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Astronomy®

HDG 08070

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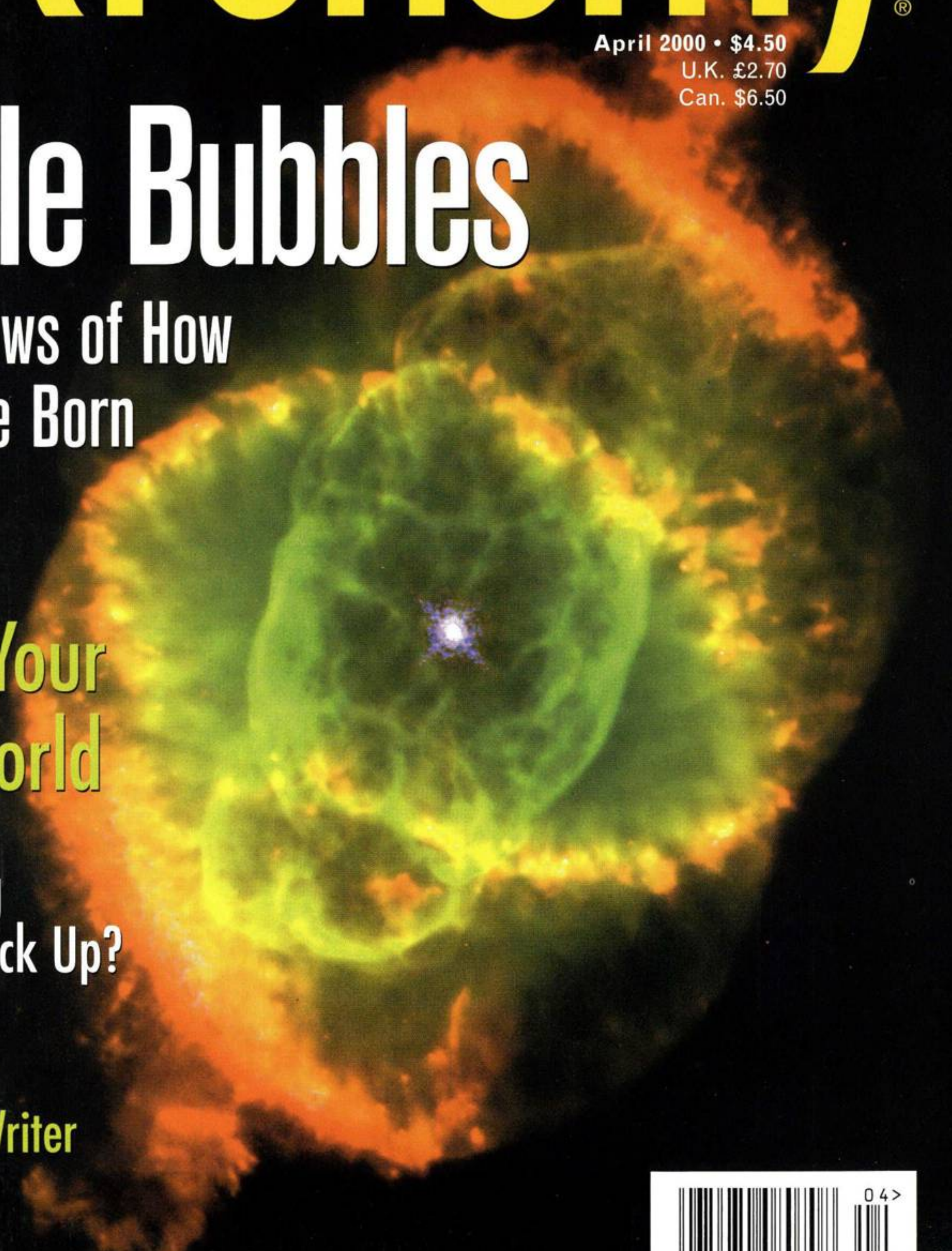

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Now two ETX apertures!
ETX-90EC — $595
ETX-125EC — $895

Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

New Fork Mount Designs with Standard-Equipment Dual-Axis Drive Systems: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

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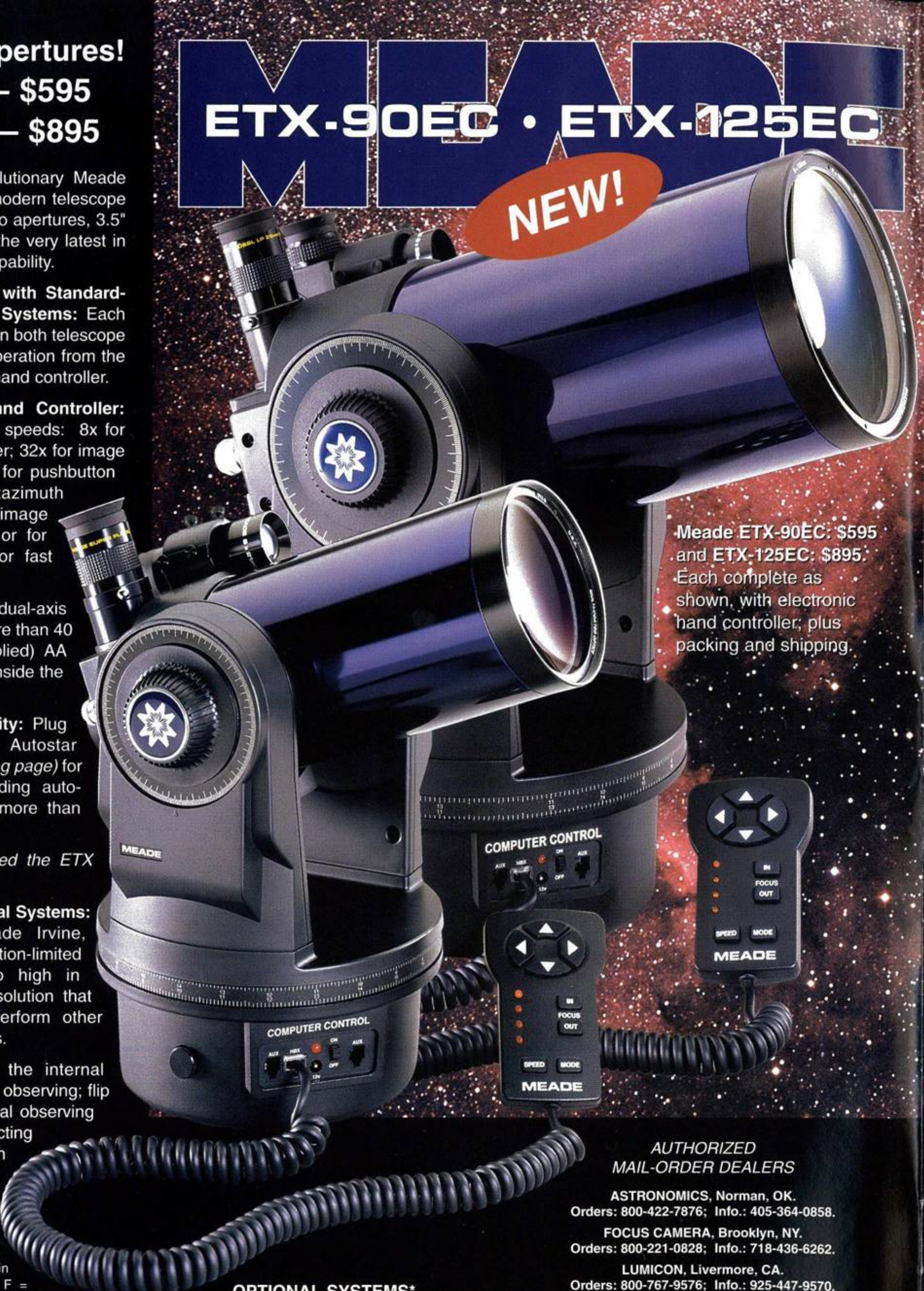
Optional Autostar™ Capability: Plug in the optional Meade Autostar computer controller *(see facing page)* for LX200-type operation, including automatic GO TO capability to more than 14,000 celestial objects.

Plus the features that created the ETX revolution:

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.



Meade ETX-90EC: $595 and ETX-125EC: $895. Each complete as shown, with electronic hand controller; plus packing and shipping.

SPECIFICATIONS: ETX-90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

OPTIONAL SYSTEMS*

#497 Autostar Computer Controller (90, 125)	$149
#880 Equatorial Table Tripod (90)	29.95
#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
#774 Hard Carry Case (90)	99.95
#775 Hard Carry Case (125)	149.95
#932 45° Erecting Prism (90, 125)	49.95
#64 Photo Adapter (90, 125)	34.95
Electric Focuser #1244 (90) *or* #1247 (125)	119.95

**see the Meade accessory ad in this issue.*

AUTHORIZED MAIL-ORDER DEALERS

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Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

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SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

EFSTONSCIENCE, Toronto, Ontario, Canada
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KHAN SCOPE CENTRE, Toronto, Ontario, Canada
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Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location …only *$149!*

ETX AUTOSTAR
RA = 08:04.6
Dec = +36°38
MEADE
ENTER
MODE
GO TO
1
2
3
4
5
6
7
8
9
0
?

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

Digital readouts of telescope position (continuously in R.A. and Dec.), menu options, glossary, and utility functions.

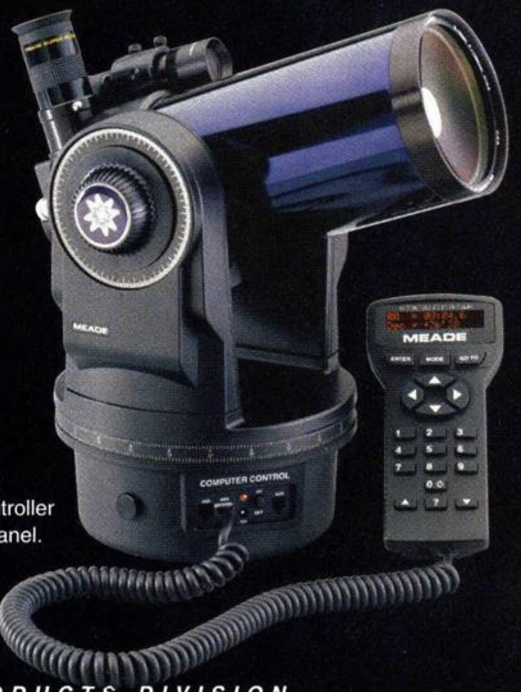
Precise sidereal-rate tracking in either altazimuth or equatorial modes. For altazimuth tracking, set the telescope on its drive base and perform a quick, easy alignment.

9-Speed Dual-Axis Operation: Pushbutton operation of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec.

RS-232 Serial Port: For operation of the telescope through a personal computer, using Meade Epoch 2000® sky software or other sky software using the LX200 protocol.

Plus: over 20 other menu options, including guided tours, major event menus, user-defined terrestrial objects, and much more.

The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**



(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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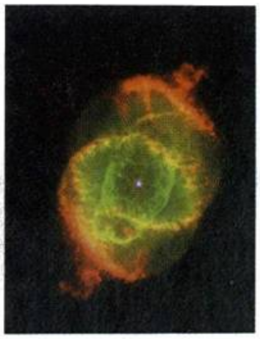
Patents pending on ETX-90EC, ETX-125EC, and Autostar.



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COVER PHOTO: Patrick Harrington (University of Maryland), et al., and NASA

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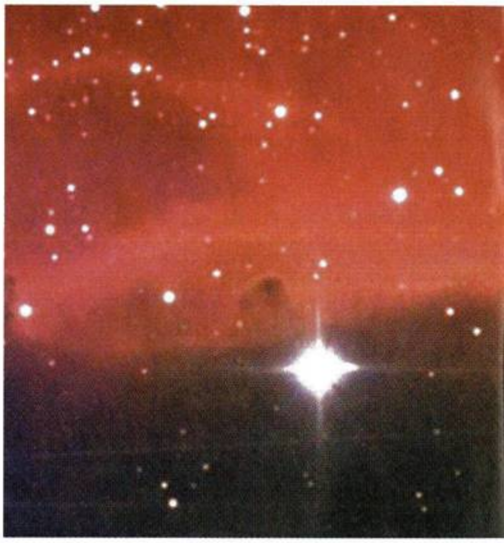

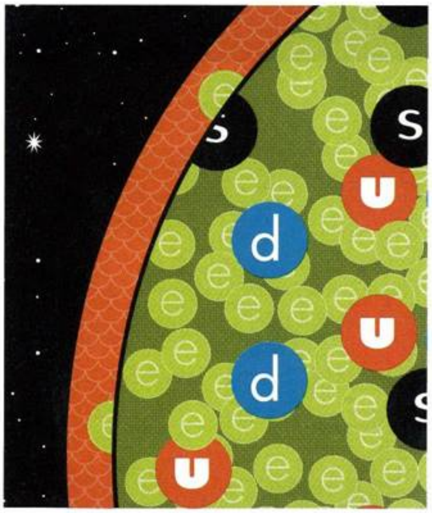

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BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Brown Dwarfs Renamed — and More

The polls have closed and the results are in: We have a winner in our "What Would You Call a Brown Dwarf?" contest. In the August 1999 issue, we asked readers to suggest a different name for these elusive objects that are bigger than planets but smaller than stars — and decidedly reddish in color instead of brown. Nearly 4,000 entries inundated our offices, providing the editors and judges with plenty of great ideas. Five leading brown-dwarf experts — Gibor Basri, Davy Kirkpatrick, Mark Marley, Eduardo Martín, and Ben Oppenheimer — weighed in with their opinions and, in a close vote, chose three winners.

Robert Naeye

First place goes to Howard Jackman of Salt Lake City, Utah, who suggested the acronym SUMO, standing for SUbstellar Massive Object. Second place belongs to Kevin Johnson of West Plains, Missouri, who was the first of many to come up with the name Substar. The third place winner is Brooke O'Klatner of Denver, North Carolina, who first suggested Planetar. *Astronomy* would like to thank the judges and all of our readers who took the time to make this contest a success. We also offer a special thanks to all the manufacturers who contributed prizes: Meade Instruments, Starlight Xpress, Astronomical Adventures, Oceanside Photo & Telescope, Parks Optical, Astronomical Society of the Pacific, Spherical Concepts, Lumicon, Day Star Publications, Edmund Scientific, Sienna Software, Cambridge University Press, and Howie Glatter.

Another piece of news brings us great pleasure to share. Robert Naeye, a writer and editor with *Astronomy* for five years, has been promoted to senior editor. Bob's work here is nothing but remarkable. He solicits and assigns about 25 stories for the magazine in any given year and edits even more. He produces the highly popular Ask Astro department and regularly writes news and features for the magazine. In his spare time he has written two books, *Through the Eyes of Hubble* and *Signals from Space: The Chandra X-Ray Observatory*. Bob has several passions including jazz, sports, and history, but astronomy remains his favorite. You can sometimes find him on the road speaking at conferences, meetings, and star parties, to which he often brings his tent, his Dobsonian, and his best girl.

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8" LX10

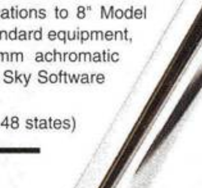
8" LX10 DELUXE

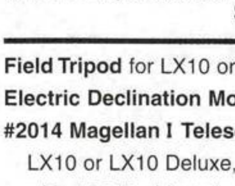
The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Series 4000 SP26mm eyepiece:** Complements the exquisite imaging of Meade 8" SC optics. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)





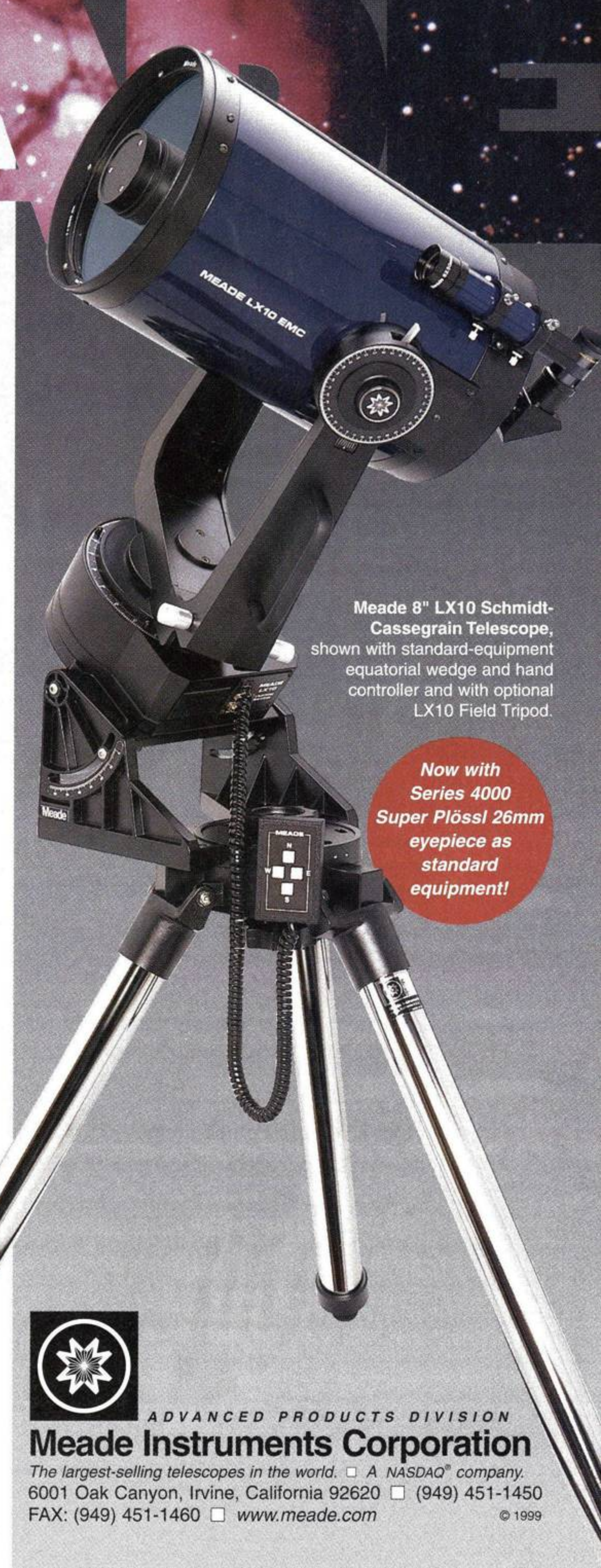
8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed; and (c) Meade Epoch 2000 Jr. Sky Software with 10,000-object database — all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; Meade #544 8 x 50mm achromatic viewfinder in place of 6 x 30mm viewfinder; and Meade Epoch 2000 Jr. Sky Software with 10,000-object database.

$1149. (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	195.
Electric Declination Motor System for LX10	95.
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	375.

The 120-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers.
Prices shown are suggested U.S. mail-order prices.



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

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Advanced technology at the most affordable prices *ever.*

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below).*

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

MEADE LX50 EMC
MEADE LX50
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Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. *Standard-equipment includes:*

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

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Meade 10" LX200 Schmidt-Cassegrain Telescope

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STARFINDER
MEADE

Complete with 1.25" rack-and-pinion focuser, 5 x 24mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Shown with optional #2010 Magellan I Computer System.

Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

Meade #77 2" Giant Rack-and-Pinion Focuser, with eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

Meade #637 6 x 30mm Achromatic Viewfinder, with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

Meade Series 4000 Super Plössl 9.7mm and 26mm multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple. **#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" — $295.** Packing & shipping in the 48 states—$15.

The lowest prices *ever* for Meade Starfinder Dobsonians — complete with these standard features:

Series 4000 SP26mm Eyepiece (1.25"): This $80 eyepiece permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities.

Professional-Grade Optical System with hand-figured optics of Grade-A fine-annealed Pyrex glass, *unlike the plate glass optics of other Dobsonians that can become thermally unstable.* Optics are multi-coated and meet the theoretical limits of resolution.

Rigid, Durable, Beautiful Dobsonian Mountings: Zero-backlash Teflon/Nylon bearings facilitate the quick location and easy tracking of celestial objects with extremely smooth motions of the telescope in both altitude and azimuth.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Strong, spiral-wound Sonotubes™ with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! Every Starfinder model opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets *in stunning high-resolution detail.* Starfinder Dobsonians are for visual observing; motor-driven Starfinder Equatorials may also be used for lunar and planetary photography, and even for limited deep-space photography.

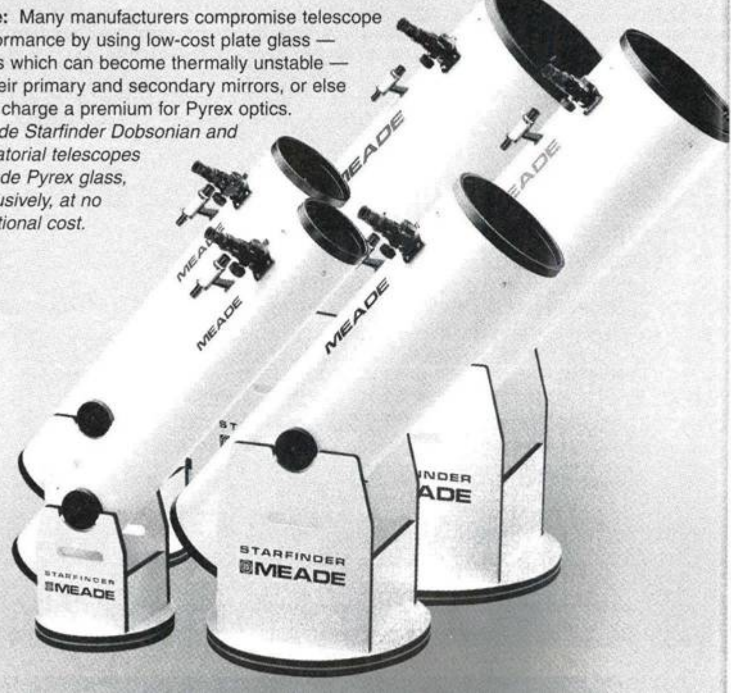
Meade Starfinder Dobsonian Telescopes

Complete per specifications above:

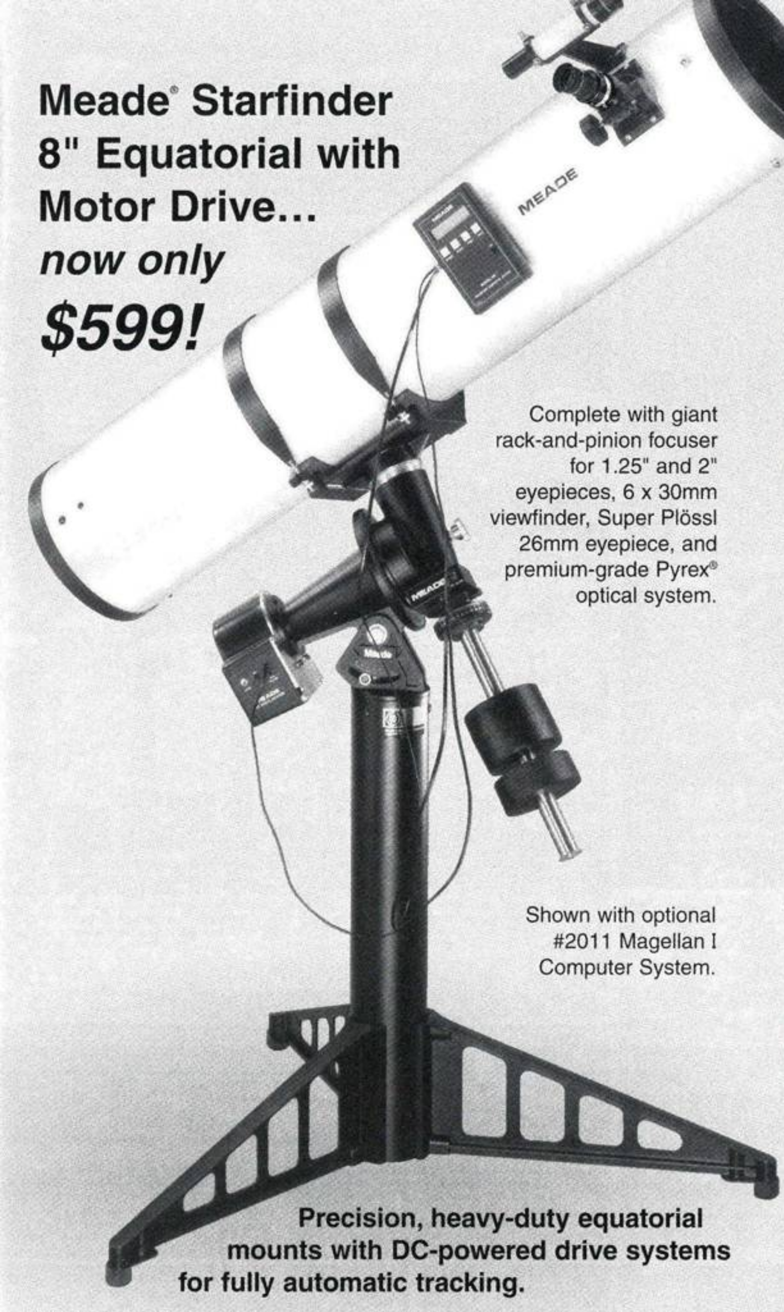
6" f/8	$249
8" f/6	349
10" f/4.5	449
12.5" f/4.8	795
16" f/4.5	1195

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Note: Many manufacturers compromise telescope performance by using low-cost plate glass — glass which can become thermally unstable — in their primary and secondary mirrors, or else they charge a premium for Pyrex optics. *Meade Starfinder Dobsonian and Equatorial telescopes include Pyrex glass, exclusively, at no additional cost.*



Meade® Starfinder 8" Equatorial with Motor Drive… *now only* *$599!*



Complete with giant rack-and-pinion focuser for 1.25" and 2" eyepieces, 6 x 30mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Shown with optional #2011 Magellan I Computer System.

Precision, heavy-duty equatorial mounts with DC-powered drive systems for fully automatic tracking.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Meade Starfinder Equatorial Telescopes

6" f/8	$499	10" f/4.5	699
8" f/6	599	16" f/4.5	2695

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

To Order any Starfinder model: contact your authorized Meade Advanced Products Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders/Info: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

Battery-Powered Cordless Drive System: For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries or from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 1.25" and 2" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 giant focuser.

MEADE
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I Telescope Computer System: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade Starfinder Equatorial 6", 8", or 10" . . . . . $295.
#2012: for Meade Starfinder Equatorial 16". . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

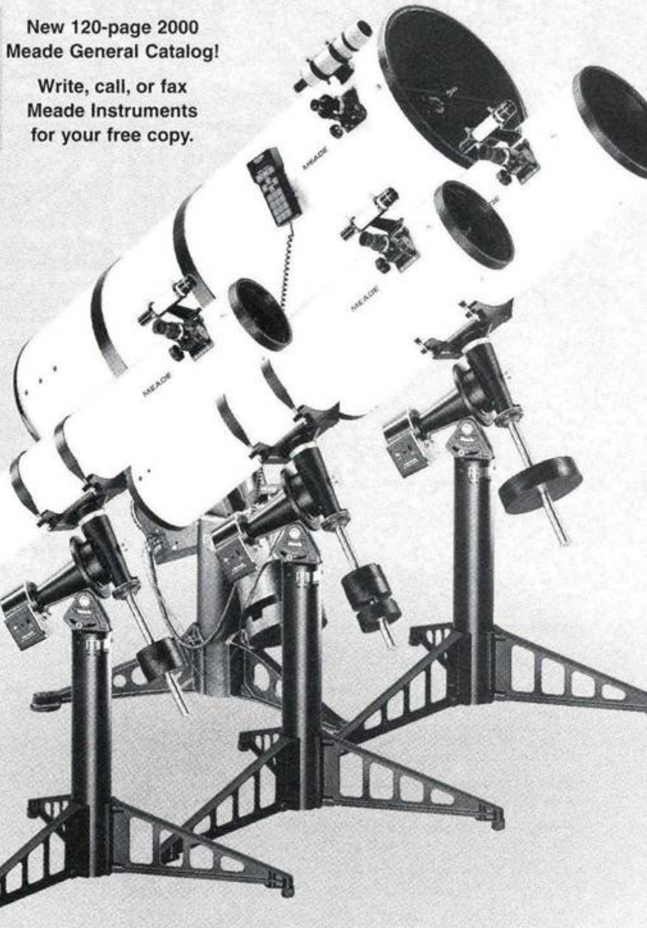
#2018: for Starfinder Equatorial 6", 8", 10" . . . . 495.
#2019: for Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I – $15, Magellan II – $20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.



ADVANCED PRODUCTS DIVISION

Meade Instruments Corporation

The largest-selling telescopes in the world. ☐ *A NASDAQ company.*

6001 Oak Canyon, Irvine, California 92618 ☐ (949) 451-1450
FAX: (949) 451-1460 ☐ *www.meade.com*

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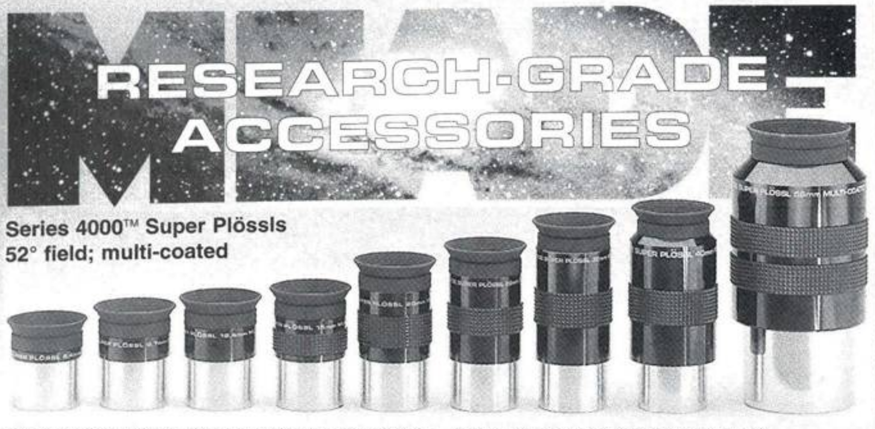


RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25". **$47.95** (4.54)

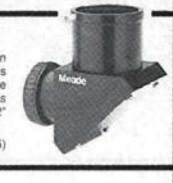
2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25". **$59.95** (4.54)

2" Diagonal Mirror



#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930**, each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces). **$42.95** (3.86)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25". **$149.95** (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery. **$169.95** (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera. **$79.95** (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

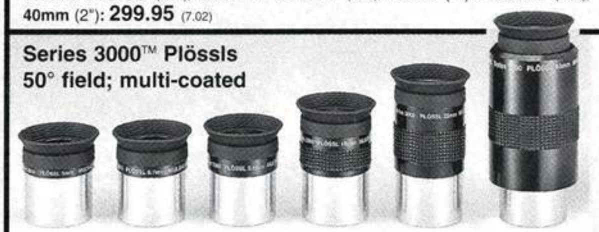
#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated



Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera. **$39.95** (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

NEW!
MEADE
FLIP-MIRROR SYSTEM

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

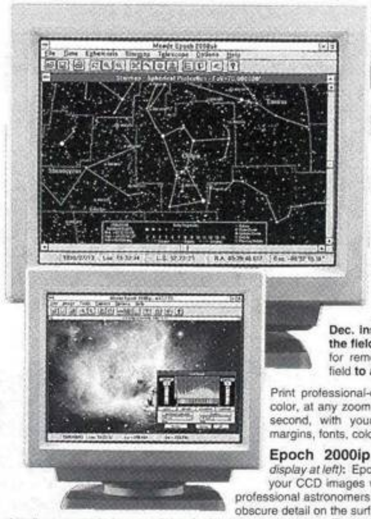
#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644

#647

MEADE
FLIP-MIRROR SYSTEM
MODEL 647



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)***:** Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$199**

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

f/3.3 CCD FOCAL REDUCER

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

MEADE
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CCD FRAMING

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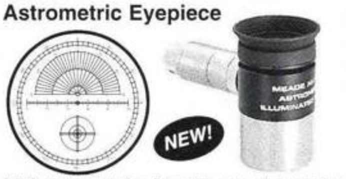

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Included with the #887 Tripod *(above),* the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications.

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Passion Quest

NASA's recent failures and the snail's pace of the U.S. Space Program have left this enthusiast disillusioned and depressed. Where have the spirit of discovery and the iron will of mid-century America gone?

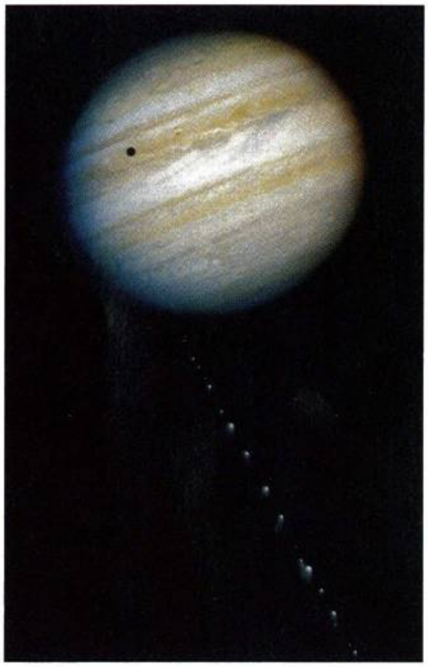
When I was three years old, I watched the first moon landing on our grainy, black-and-white TV set. Outside, I looked at the full moon and thought to myself, "Neil Armstrong is up there right now!"

I imagined him hop-skipping across the white-gray powdery surface and jouncing along in the moon buggy. I pictured his life as being full of adventure and my future among the stars a reality. I remember thinking: "If we're on the moon now. . . . Imagine where we'll be when I'm grown up." I dreamed wonderful dreams of swashbuckling astronauts exploring exotic planets rife with life and intelligence. Mars was, of course, long inhabited before I became an astronaut in my imagination. There were cities full of Earth-born "Martians," and transportation there was as cheap and common as a bus ride to school.

I couldn't have been more wrong.

In my teen years, long after the Apollo program limped and floundered its way into oblivion, I discovered a much sought-after surrogate: science fiction. Now new worlds were only a paperback away! Hundreds of volumes vanished into the unslakable furnace of my eyes and mind. I tore through Asimov, Heinlein, Clarke, Van Vogt, Bester, Silverberg, and Harrison. I devoured Anthony, Burroughs, Bova, and hundreds of others.

Now I'm an adult. I still enjoy the odd science-fiction novel, but I've come to realize that something is missing. We have fallen so far short of the dreams of my youth that I simply cannot express the bitter disappointment of a man who realizes he will never stand on the sands of Barsoom. I will never awake to the thrum of the hyperdrive or stare out of the port in my stateroom at the infinity of space from the darkness between the stars off the shoulder of Orion.



Fragments from Comet Shoemaker-Levy 9 crashed on Jupiter in 1994. NASA

Feel my passion. Let it infect you and subsume you. From my inexplicable loss let grow a determination like that which drove past explorers of the world and mind. I invoke the scientists, adventurers, inventors, and dreamers to continue the pursuit. If I could grab the whole world between my fists I would shake it and scream, "Wake up! The universe is ours!" — *Troy Boyle, Erlanger, Kentucky*

"G," What a Mistake!

I noticed an error in your January 2000 issue concerning one of your top ten picks of the best sky events for the 20th century. Choice number one — the Shoemaker-Levy 9 collision with Jupiter — contained a large numerical mistake in the estimated energy released in the impact of the "G" fragment. According to the article, the energy released was equivalent to six million tons of TNT. When I recalculated it, the actual amount of energy released was in the vicinity of 6,000,000,000,000 tons (or six million megatons) of TNT — about 600 times the estimated arsenal of the world. — *David A. Still, Kingston, Ontario,Canada*

A Little Eccentric

I'm disappointed that in the January 2000 issue you published an incorrect answer to "Can you explain why the earliest sunset occurs on December 8, 1999?" You had a similar incorrect explanation in a December issue three or four years ago. The effect is caused "primarily" by the tilt of Earth's axis relative to its orbit, not the eccentricity of Earth's orbit.

While the eccentric orbit has an effect, it is much less than the tilt. Even if the orbit were perfectly circular, we would still have earliest and latest sunrises and sunsets out of synch with the solstices. — *Curtis Croulet, Temecula, California*

Mea Culpa. *I erred. If Earth's orbit were a circle and Earth's axis were not tilted, days and nights would be the same length, so there would be no "shortest day." The equation of time — which governs the difference in the actual position of the sun versus the mean position of the sun in the sky — depends on both Earth's tilt and the orbital eccentricity. If you measure the time the sun crosses the meridian, for example, then Earth's tilt can change that time by as much as nine minutes, and the orbital eccentricity changes by as much as 10 minutes. Therefore, both effects are roughly equal and are independent of one another. We'd have one even if the other didn't exist.*

I hope this clears it up. — Phil Plait, Advanced Computer Concepts, Inc.; website: http://www.badastronomy.com.

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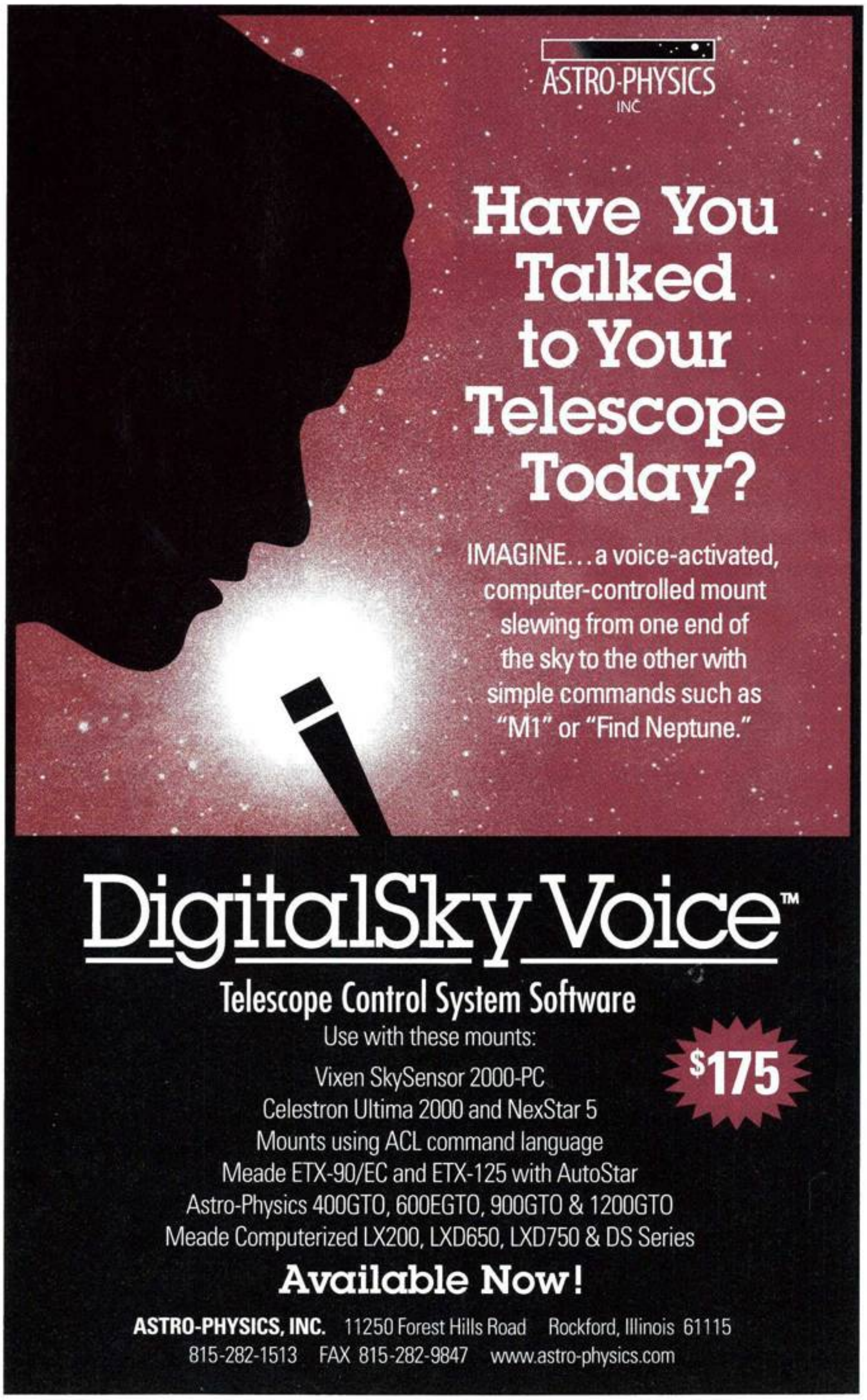

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Expanding Astro

As a longtime subscriber to *Astronomy* magazine, I've always enjoyed the "Ask Astro" section for its simple answers to basic astronomy questions. However, in the February 2000 issue, I was surprised to read Robert Naeye's answer to the following question: "If the universe is expanding, would the space between atoms be expanding? Am I expanding?"

Naeye explains that objects with enough mass (including people and atoms) overwhelm the universe's expansionist tendencies. While the answer to the question is indeed no, Naeye's reasoning is erroneous. Gravity does rule, but only in astronomical scales/masses. Gravity has nothing to do with why atoms, people, or buildings do not follow the Hubble flow and expand.

Gravity is negligible in an atom; the electric force between a negatively charged electron orbiting the nucleus of a hydrogen atom and the positively charged nucleus itself is nearly 40 orders (that is one followed by 40 zeros) of magnitude stronger than their mutual gravitational attraction. Therefore, the electromagnetic force and molecular bonding determine the expansionist behavior on those scales.

Please clarify this misconception. Keep up the good work. Your magazine is great. — *Vassilis Charmandaris, Cornell University, Ithaca, New York*

The gist of my answer was correct, but as Dr. Charmandaris points out, the idea here is to think in relative terms. The electromagnetic force clearly dominates at minute scales, such as in atoms or even in the human body. For planet-sized or larger objects, gravity halts cosmic expansion. Many thanks for catching this error. — Robert Naeye A

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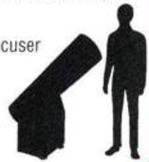

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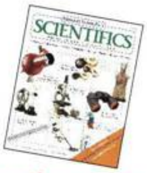

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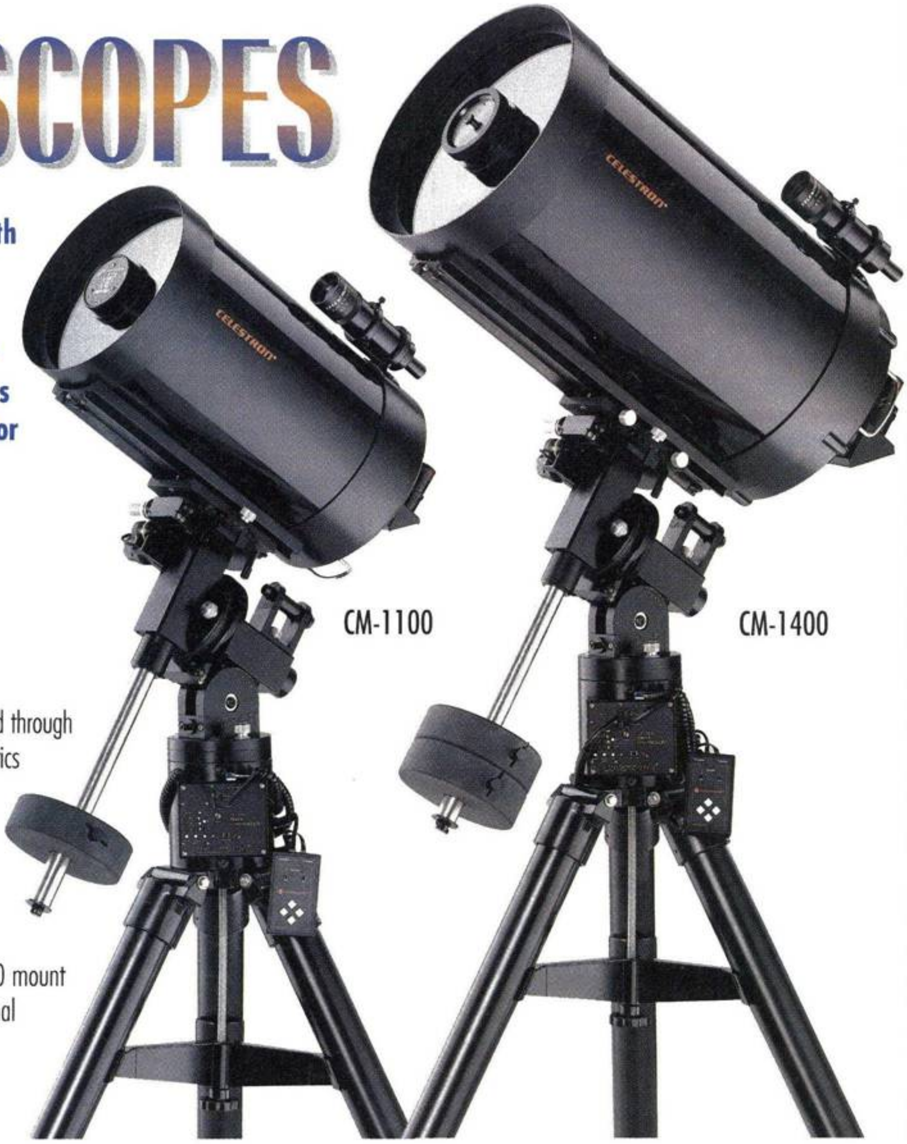

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The standard, compact hand controller operates the various functions such as position, identify, speed, pointing, etc.

8 tracking and slewing speeds are available – sidereal, solar, lunar, King, 2x sidereal, 0.5x sidereal, 2° per second, 10° per second.

The Ultima 2000 has impressive pointing accuracy where the object selected will always be in the field of view of a low to medium power eyepiece. Includes Enhanced Encoder Resolution and Relative Go To mode for increased accuracy which is ideal for centering objects on a CCD chip.

The software database contains over 10,000 deep-sky objects as well as major planets. The objects include the entire Revised New General Catalog, the Messier catalog, selected objects within the IC catalog and the ESO and Uppsula catalogs, 241 interesting double and multiple stars, and 661 non-stellar objects. The database may not be the largest in the industry but it is one of the most useful because of the object selection. In addition, the display of the object data is the most complete of any commercial computerized telescope.

For beginners and educators, a special Tour mode is available which allows you to view 15 popular objects by season, automatically.

To quickly and easily find your favorite objects, the telescope offers 25 user-defined selections.

The Ultima 2000 can by operated by a computer using popular astronomy software such as *The Sky*. Programs can also be written by the user to control the telescope.

Other standard features and accessories include: 9x50 finderscope, multi-coated 26mm Plössl eyepiece – 1¼" (78x), star diagonal – 1¼", LED display, auto guider port, northern and southern hemisphere operation, comprehensive instruction manual.

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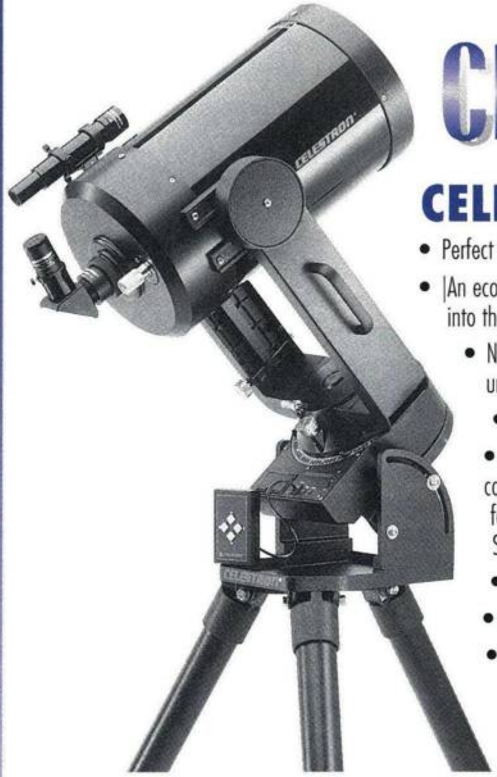
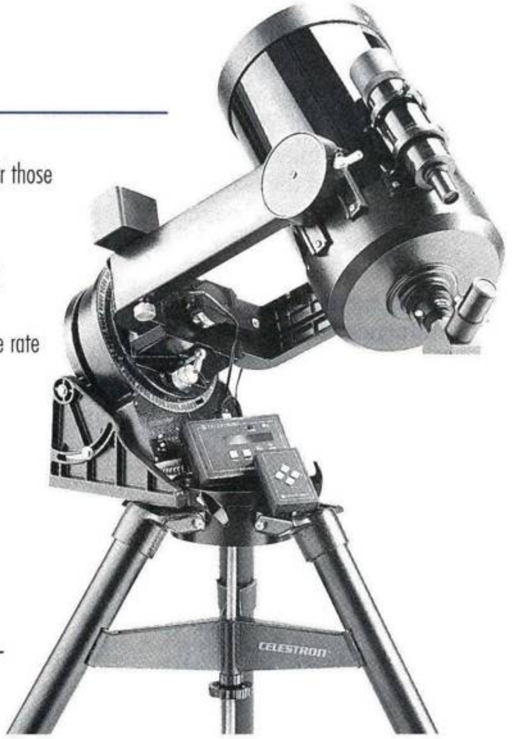


CELESTAR 8 TELESCOPES

CELESTAR 8

- Perfect for a first time astronomer.
- An economical but full featured 8" (2032mm f/10) Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8.
- No sacrifice was made in the optics. Celestron's carefully hand-figured system delivers diffraction-limited optics of unsurpassed quality. Starbright® coatings are standard.
- The energy efficient DC electronics are powered by a 9 volt alkaline battery for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the Sky & Telescope review – "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90.°
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).
- Weight – 41 pounds.



CELESTAR 8 DELUXE

- For the more serious astronomer.
- This telescope utilizes the same superior optics and has all the features of the Celestar 8, but is enhanced, for those who prefer a premium version.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this advanced drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging with the PixCel or other CCD cameras.
- Fastar compatible for f/1.95 CCD imaging – deep sky images in 30 seconds or less!
- Made in the U.S.A.
- The standard accessories for this telescope include: Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod with adjustable height that's exceptionally rigid and sturdy .
- Also standard is a large 9x50 Finderscope, Star Diagonal – 1¼" and a multi-coated 26mm Plossl Eyepiece – 1¼" (78X).
- Weight – 52 pounds.

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Advanced Astro Master

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Contains an RS-232 serial interface to enable usage with programs like "The Sky"™ by Software Bisque.

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THE MILKY WAY HALO

White Dwarfs by the Trillions?

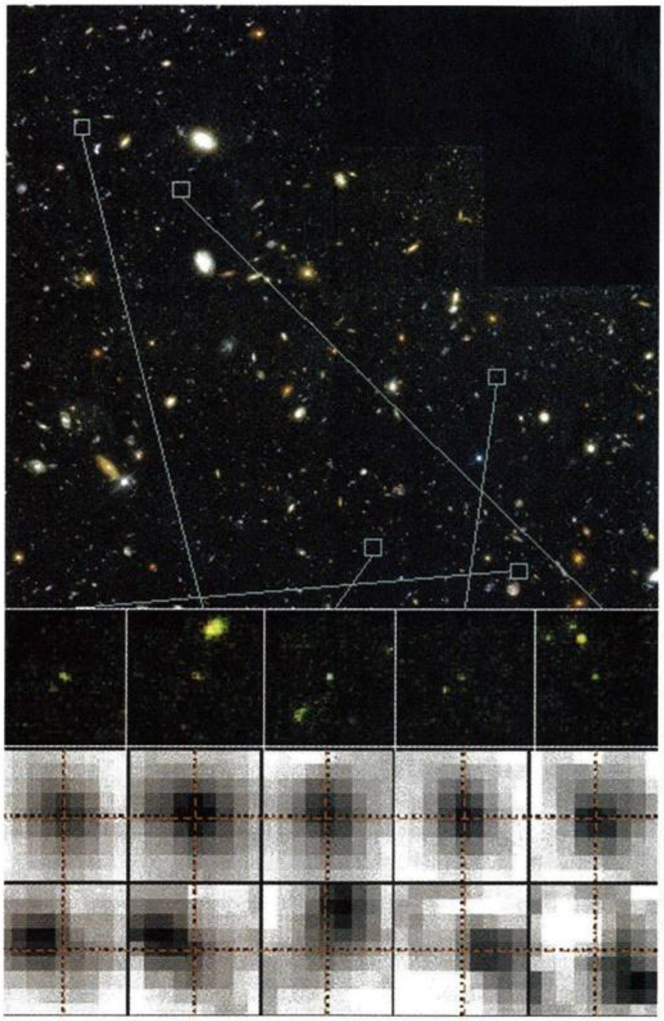
▶ Several independent lines of evidence are leading astronomers to a simple yet profound realization: The Milky Way Galaxy may harbor an enormous population of ancient white-dwarf stars. Previously undetected, these old white dwarfs could be far and away the most common type of star in the Galaxy. But because they are burned out stars that lack an internal energy source, they have faded to virtual invisibility.

If confirmed, these white dwarfs would partially explain one of astronomy's most enduring mysteries — the nature of the Galaxy's dark matter. Dark matter constitutes more than 90 percent of the Galaxy's mass, exerting gravitational influence but emitting little or no light. Most of the dark matter resides in the halo, an enormous region of space that surrounds the Galaxy's visible disk.

The first line of evidence that much of the dark matter could be locked up in old white dwarfs comes from the MACHO collaboration. This international team of astronomers looked for massive, dark objects in the Galaxy's halo by detecting how these objects act as gravitational lenses. After nearly six years of observations, the team detected more than 20 lensing events. These events appear to have been caused by objects about half the sun's mass. Ordinary stars of this size would have been seen visually, but ancient white dwarfs would have this mass and be practically invisible. Based on the number of events, the white dwarfs would account for about half the Galaxy's dark matter.

But the MACHO results raised as many questions as they answered. Where did these white dwarfs come from? Where are the heavy elements their progenitor stars should have produced?

Some astronomers also wondered why nobody had imaged one of these white dwarfs. It's possible that previous searches missed them because astronomers assumed that old white dwarfs would look red. But recent theoretical models by Brian Hansen of Princeton University demonstrate that old white dwarfs should appear blue.



Rodrigo Ibata (ESO), Harvey Richer (Univ. of British Columbia), et al., and NASA

Five faint, blue objects in the Hubble Deep Field moved slightly over two years, implying they could be white dwarfs in the Milky Way's halo.

1951
1987
1994

N. Hambly and S. Hodgkin, et al.

The rapid motion and inclined orbit of an ancient white dwarf (tick marks) show that it spends most of its time in our Galaxy's halo.

In September 1999, a team led by Rodrigo Ibata of the European Southern Observatory and Harvey Richer of the University of British Columbia reported what appear to be five very faint objects that moved slightly between Hubble Deep Field images taken in December 1995 and December 1997. The brightnesses, colors, and motions of these objects are consistent with old white dwarfs in the Milky Way's halo. Richer adds, "The numbers we're finding are consistent with the MACHO results. A trillion white dwarfs would supply half the mass of the Galaxy." Hubble observations originally scheduled for December 1999 could have confirmed the motions, but they had to be postponed until December 2000 because of the telescope's failed gyroscopes. (See "A Hubble Makeover," page 26.)

In the January 6, 2000, *Nature*, a British/American team led by Simon Hodgkin

G-8

CELESTRON TELESCOPES

SCHMIDT-CASSEGRAIN • REFRACTOR • NEWTONIAN

Large Aperture Telescopes with Unequaled Optical Excellence + a Superb German Equatorial Mount = Real Value

OPTICS: **G-8 Telescope** – 8" f/10 Schmidt-Cassegrain
G-9¼ Telescope – 9¼" f/10 Schmidt-Cassegrain
G-8N Telescope – 8" f/5 Newtonian
CR-150 Telescope – 6" f/8 Refractor

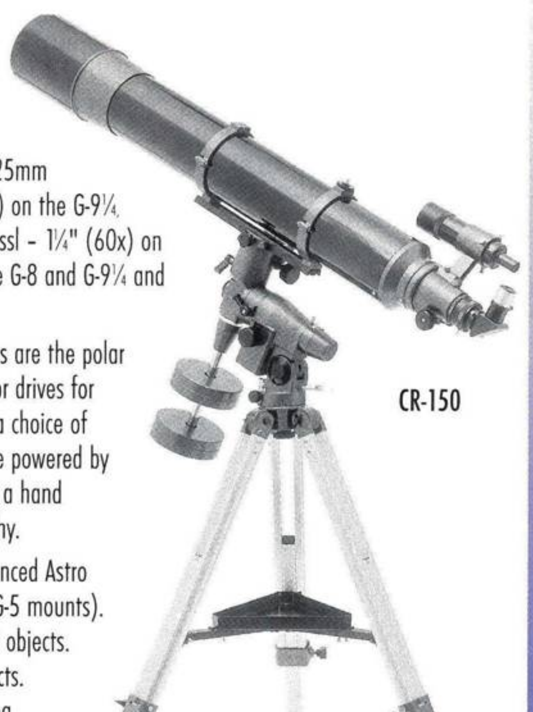
G-8N

Both of the Schmidt-Cassegrain systems are made in the U.S.A. and feature hand-figured, diffraction-limited optics along with Starbright® multicoatings. The fast (f/5) Newtonian is made to Celestron's uncompromising standards. The Newtonian's proprietary optical design incorporates an auxiliary correcting lens to reduce aberrations, flatten the field and allow a short tube design for added portability. The 6" refractor is a fully multicoated achromat which delivers excellent images at an incredibly low price.

G-9¼

MOUNT: All four telescopes use the CG-5 German mount. The CG-5 mount is the newest generation of Celestron's German mounts which was designed by Celestron. Now, preloaded bearings in R.A. are standard (for added smoothness) which competitive models do not offer. Both axes of the equatorial mount have precision worm gears for extremely smooth motion and excellent tracking accuracy.

This heavy-duty mount easily delivers jitter-free images and the sturdy adjustable height aluminum tripod has excellent damping characteristics. A convenient deluxe accessory tray adds to the stability of the system.



CR-150

ACCESSORIES: Numerous accessories are available for these telescopes. Included as standard eyepieces – 25mm SMA - 1¼" (81x) on the G-8, 26mm Plössl - 1¼" (90x) on the G-9¼, 20mm Plössl - 1¼" (50x) on the G-8N, and 20 mm Plössl - 1¼" (60x) on the CR-150. The standard finderscope is a 6x30 with the G-8 and G-9¼ and a 9x50 with the G-8N and CR-150.

Some of the more useful accessories for these telescopes are the polar alignment scope (for fast polar alignment) and DC motor drives for automatic tracking of celestial objects. Celestron offers a choice of motor drives – a single axis (R.A.) or dual axis. They are powered by four D-cell batteries (not included). Both models include a hand controller with built-in drive corrector for astrophotography.

Computerize your telescope by adding the optional Advanced Astro Master® which is easily installed (use kit #93913 for CG-5 mounts). Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery. Contains an RS-232 serial interface to enable usage with programs like "The Sky" by Software Bisque.

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CELESTRON® 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835 of the University of Leicester reported the identification of an old white dwarf with colors matching Hansen's models. With a temperature of only 3500 kelvins (5800° F), this is the coolest white dwarf ever seen. Although only about 90 light-years away, its fast motion across the sky and inclined orbit imply that it spends most of its time in the Milky Way's halo. "We have only searched a small volume, so the existence of one nearby halo white dwarf implies there could be huge numbers of these objects," says Hodgkin.

Not all astronomers are convinced that old white dwarfs constitute half the Galaxy's dark matter. "I am skeptical about the evidence for a massive halo of white dwarfs, but it is too early to firmly reject it or accept it," says Princeton theorist Bohdan Paczynski. And Chris Flynn of Tuorla Observatory in Finland, who has searched previous sky survey images for old white dwarfs, says, "If there were sufficient numbers of them to solve the dark matter problem in the Galaxy, then there would be dozens of them in the other surveys we looked at — and there aren't."

University of Chicago astrophysicist Evalyn Gates and her colleague Geza Gyuk of the University of California at San Diego may have found a solution. Rather than an enormous spherical halo containing one trillion old white dwarfs, they propose that the Galaxy has a puffed-out disk of about 150 billion old white dwarfs. "Filling the halo with white dwarfs creates really big problems," says Gates. "But our model is the first time that the microlensing data has made sense. — ROBERT NAEYE

EXTRASOLAR PLANET

Light of a Distant Planet

▶ In the quest to find worlds beyond the solar system, a team of British astronomers may have achieved a long-awaited milestone: detecting light, albeit glimmers, from a planet orbiting a distant star.

Sorting tediously through spectra collected at the edge of technological capabilities, the astronomers report they have sifted out traces of light from a blue-green gaseous giant orbiting the star Tau Boötis, which is located 50 light-years from Earth.

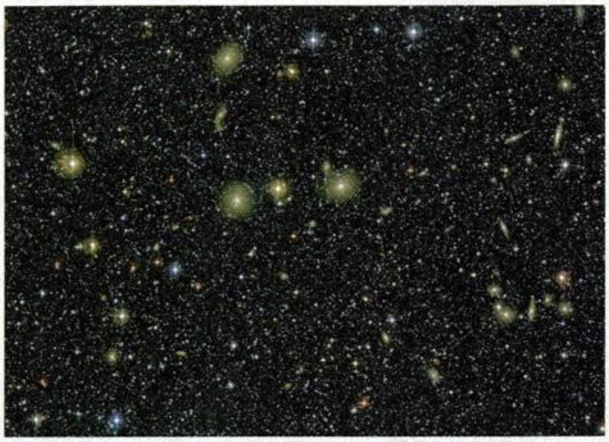
The image, gathered by Andrew Collier Cameron of the University of St. Andrews, Scotland, is not a sharp, conventional one, like the familiar faces of planets in Earth's solar system. The distance to the star is just too great. Even so, the sighting provides independent evidence for extrasolar planets whose existence mostly had been inferred by the slight wobbles they induced in the motions of their parent stars. It also opens the door for the first time to studying these planets.

Cameron's team reports in the December 16, 1999, issue of *Nature* that it has collected faint photons of the planet's light manifest in spectra of the star-planet pair. The planet, which lies very close to Tau Boötis and has a scant 3.3-day orbital period, appears in the spectra as a Doppler shift, into the blue as the planet moves toward the observers and as a red shift as the planet moves away. The light samples also provide the indication of the planet's blue-green color.

Cameron's discovery needs to be confirmed, others caution. Researchers at the National Center for Atmospheric Research's High Altitude Observatory in Boulder, Colorado, tried similar observations earlier but concluded they could not detect the planet's light in the glare of the star, which is 10,000 times brighter. The Cameron finding might just be noise in the data.

Veteran planet hunter Paul Butler of the Carnegie Institution's Department of Terrestrial Magnetism said the two searches at Tau Boötis, nonetheless, help bring planetary astronomy to a new plateau, adding, "We are entering an era when extrasolar planets can be studied as physical and chemical entities in their own right."

THE GREAT ATTRACTOR



European Southern Observatory

Astronomers who want to study large-scale structures in the universe typically point their telescopes and cameras away from the "Zone of Avoidance," the disk of the Milky Way where local stars and dust obscure distant objects. But the modern electronic detectors of the new Wide Field Imager (WFI), which is attached to a 2.2-meter telescope at the European Southern Observatory in Chile, can look directly into this region to capture background galaxies.

Norma the Square, a constellation in the southern sky, was the location for the WFI's picture. Previously unseen dwarf galaxies and about 200,000 stars in the Milky Way (seen as white dots) are visible. This region of sky contains the "Great Attractor," an area where a huge concentration of galaxies seems to be pulling on surrounding galaxies, including our own. The central region of the Attractor lies about 250 million light-years away. The yellow spiral galaxy near the image's top center appears to be undergoing a stretching due to the larger galaxies seen above and below it. The cannibalization of many of these galaxies is expected as they hurtle ever closer to one another.

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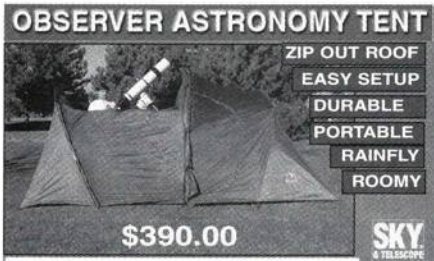

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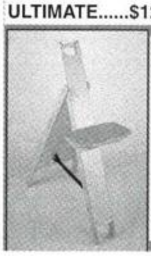

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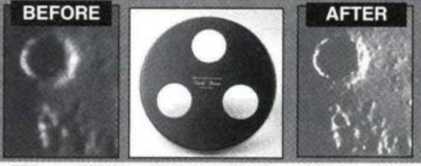

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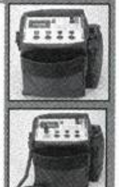

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The star was the search target because the planet there was already known — it was one of the approximately 30 extrasolar planets whose presence has been inferred by their gravitational tugs on stars. Cameron's team calculated the planet is about eight times the mass of Jupiter and 1.8 times the diameter.

Astrophysicist Adam Burrows of the University of Arizona said that in some sense, it probably does not matter which team is right about having spotted the planet. Now, more searchers will likely enter the fray, perhaps with better equipment, and observe this and other planets.

And collecting more light to achieve better spectra will open the door to doing actual scientific investigations. Says Butler: "The direct detection of a planet's spectrum would be a great triumph and would give us unique physical and chemical information about the planet, including orbital inclination, mass, radius, density, temperature, rotational period, and chemical composition." — **David Graham**

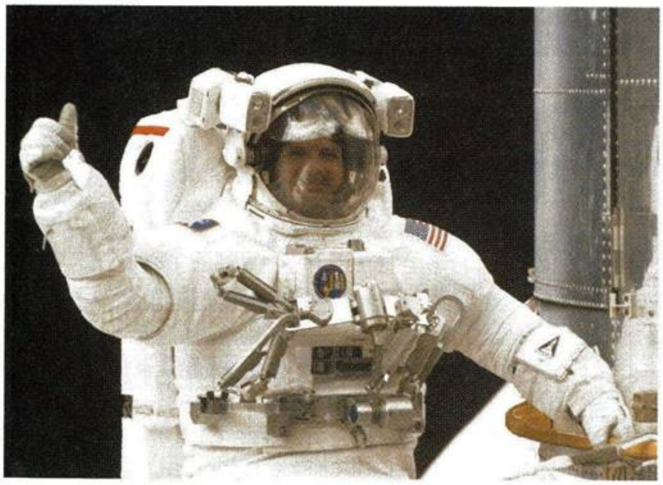
NASA SUCCESS

A Hubble Makeover

▶ The Hubble Space Telescope awakened from its five-week electronic hibernation after space shuttle Discovery's astronauts performed needed repairs in late December. The $3-billion Hubble shut itself down and entered a "safe mode" on November 13, 1999, when the fourth of six gyroscopes failed because of corroded wires.

Before Discovery could launch to remedy the situation, the shuttle encountered its own set of problems, including damaged wiring, a contaminated engine, a dented fuel pipe, welding irregularities, and inclement weather. After a record nine delays, Discovery finally began its 27th mission on the evening of December 19. Astronauts worked throughout the Christmas holidays repairing or installing nearly $70 million worth of updated equipment and allowing Hubble to open its eyes again.

Astronaut Steve Smith waves to a crewmate inside Discovery's cabin during the first spacewalk to repair the Hubble Space Telescope.



NASA

Hubble needs a minimum of three working gyroscopes to keep itself properly oriented. While in safe mode, Hubble kept its solar arrays perpendicular to the sun by rotating about once an hour — negating the opportunity for any precise aiming of observational equipment and rendering Hubble virtually blind for this period. Working or not, Hubble costs about $25 million a month to operate.

Because the main gyroscopes didn't function properly, simply snagging Hubble challenged Discovery's crew members. A straightforward approach to grabbing Hubble was impossible. Its off-kilter position required Discovery's pilot, Curtis Brown, Jr., to finesse his spacecraft's position to align with the orbiting observatory. Meanwhile, backup gyroscopes fired to eliminate the telescope's rotation and keep its solar arrays properly oriented while Brown maneuvered Discovery into position. European Space Agency astronaut Jean-François Clervoy then grabbed Hubble with the shuttle's robotic arm.

On December 21, spacewalkers Steve Smith and John Grunsfeld spent more than eight hours performing repairs — half of which was spent replacing Hubble's six 24-pound gyroscopes. Despite the fact that several of Hubble's systems were malfunctioning or shut down, Grunsfeld was impressed with HST's overall condition. "Once you got past the superficial blemishes and looked inside, Hubble looks absolutely pristine," he says. Smith and Grunsfeld also installed six voltage regulators on Hubble's batteries to prevent overheating. Additionally, the astronauts opened a coolant line on the disabled infrared camera, NICMOS. Shuttle-bay-door latches that resisted closing made this space walk the second longest in history.

Two days later, American Michael Foale and Swiss astronaut Claude Nicollier performed "brain" surgery in space when they replaced Hubble's computer with a radiation-resistant Intel 80486 DX2 processor. The replacement computer is 20 times faster than its predecessor and gives Hubble's memory a six-fold increase. While today's computer technicians consider the DX2 obsolete, NASA prefers time-tested equipment.

During the third and final space walk on December 24, Smith and Grunsfeld returned to the shuttle bay. Installation of a solid-state recorder allows Hubble to record 10 times as much data as before. A new radio transmitter replaces a backup unit that took over in 1998. Designers never expected the radio transmitters to fail, so working on them required special tools and a redesigned replacement unit.

Grunsfeld's hands tired easily in the bulky gloves during the procedure, which lengthened the time needed to complete the task. After the men hooked up an electronic unit to the pointing system and hung two 4x5-foot stainless steel solar guard panels over cracked and peeling insulation at Hubble's base, NASA declared the mission a success.

Discovery touched down in Florida on December 27, 1999, with just one day to spare before possible Y2K problems. — **Carol Ryback**

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DARK MATTER

Astronomers Detect Galaxies' Hidden Masses

▶ Astronomer Vera Rubin discovered three decades ago that spiral galaxies, like icebergs floating in seawater, hide most of their mass from view. The dimensions of galaxies had eluded detection until astronomers with the Sloan Digital Sky Survey (SDSS) stacked the images of 29,000 relatively nearby galaxies on top of each other. The statistical technique allowed them to detect halos extending about 1.3 million light-years from their galactic cores.

This so-called dark matter extends well beyond the galaxies' stars and its presence suggests that galaxies are twice as large and twice as massive as previous studies indicated. The discovery, to be reported in *The Astronomical Journal*, suggests that the Milky Way and the Andromeda Galaxy (M31), which are separated by approximately 2.2 million light-years, are closer than their stars alone would suggest.

"I know no word but 'spectacular' to describe this," says Rubin, of the Carnegie Institution of Washington. "What is really mind-boggling is to consider what this team will know a year from now."

The 37 astronomers on the SDSS team, led by University of Michigan astronomer Philippe Fischer, made their discovery with data collected during two nights of observations in March 1999. The observations were start-up tests of the SDSS's 2.5-meter telescope in the Sacramento Mountains east of Alamogordo, New Mexico. Full-scale scientific observations will begin in April 2000, continue for five years, and culminate with a detailed, three-dimensional map of the distribution of a million galaxies in a volume extending out to nearly 2 billion light-years over 25 percent of the sky.

The Sloan Digital Sky Survey team discovered halos of dark matter around many relatively nearby galaxies, such as NGC 4437 in Virgo. Stephen Kent / SDSS Collaboration

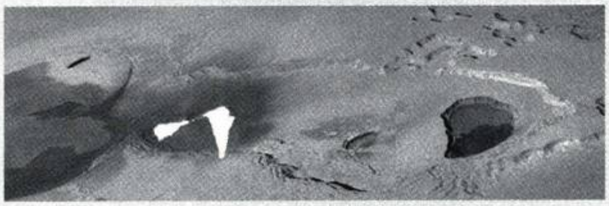
Amid the excitement over the SDSS's initial results, astronomers have proposed building 6- and 8-meter telescopes to be positioned around the globe to survey the remaining sections of uncharted sky. "By the end of this next century we will probably have a catalog of the entire observable universe, including all 100 billion galaxies," says Michael Turner, a University of Chicago cosmologist and spokesperson for the SDSS team.

The SDSS scientists took advantage of Einstein's general theory of relativity. According to the theory, the gravitational pull of matter in the universe deflects rays of light coming from more distant objects like sunlight passing through a magnifying lens. This effect is much larger than the microlensing used by the MACHO project (see "White Dwarfs by the Trillions?" page 22) to detect white dwarfs in the halo of the Milky Way Galaxy.

In this case, the SDSS team was able to measure the galaxies' lensing effects only because the telescope's digital detector, which is the size of a table, is designed to record a monumental amount of data during each night. Dark matter around the 29,000 foreground galaxies imaged in March 1999 collectively distorted the shapes of hundreds of millions of galaxies behind them by about 0.3 percent. (The observations provide no clues about the nature of the dark matter.) No other telescope in the world could detect such weak lensing.

Eventually, the survey data collected by the SDSS will be available via the Internet to other astronomers and the public, allowing anybody to conduct astronomical research at computer keyboards instead of at mountaintop observatories. "My generation grew up in an era when data were very limited," says Rubin. "I really do think that this changes the way astronomy will be done in the future." — Rex Graham

GALILEO MISSION



NASA/JPL

The Galileo spacecraft has sent back the sharpest images yet of Jupiter's volcanic moon Io. Taken on November 25, 1999, the image above shows a fountain of lava shooting more than a mile above the surface. (The lava was so bright that it overloaded the camera's detector, producing the white blur.) Planetary scientists think the lava erupts out of a fissure represented by the wavy line and has a temperature of at least 1000 kelvins (1300° F).

The flat-topped mesa on the right of the image has scalloped margins, which are typical of what geologists call "sapping." In this process, fluid escaping from the base of a cliff erodes the surrounding area. On Earth, springs of groundwater create these features, and similar features on Mars are key evidence that water once existed there. Scientists suspect that the liquid on Io is pressurized sulfur dioxide. The liquid changes to a gas instantaneously upon reaching the surface, blasting away material at the cliff's base.

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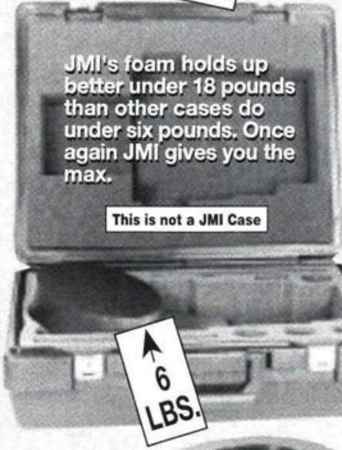

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NGT-6 Update:
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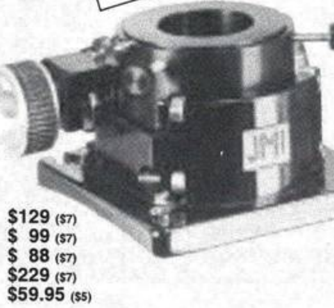

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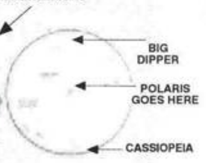

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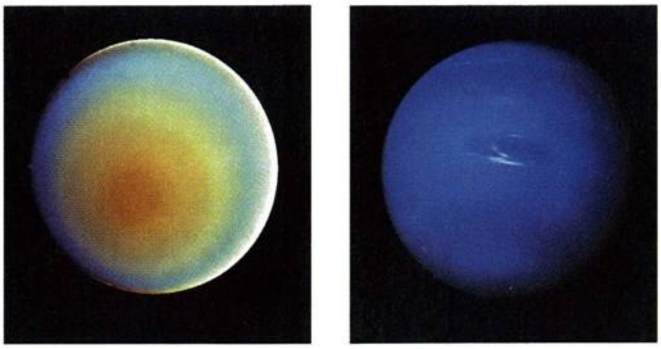

A new theory proposes that Uranus (left) and Neptune formed much closer to the sun and then moved out to their current locations. NASA/JPL

PLANET FORMATION

Birth of Uranus and Neptune

▶ Pssst . . . astronomers who model the formation of the solar system have kept a dirty little secret: Uranus and Neptune don't exist. Or at least computer simulations have never explained how planets as big as the two gas giants could form so far from the sun. Bodies orbited so slowly in the outer part of the sun's protoplanetary disk that the slow process of gravitational accretion would need more time than the age of the solar system to form bodies with 14.5 and 17.1 times the mass of Earth.

But in the December 9, 1999, *Nature*, Edward Thommes and Martin Duncan of Queens University in Ontario and Hal Levison of the Southwest Research Institute in Colorado report a possible way to get around the problem. Maybe Uranus and Neptune began forming closer to the sun, where there was more material to make giant planets and the timescales are much shorter.

The team ran 24 simulations that assumed four or five ice-rock cores formed between 5 and 10 astronomical units (one AU equals the Earth-sun distance) from the sun. Each contained about 10 Earth masses. In just 100,000 years, the innermost core swept up enough gas to form a Jupiter-sized planet. The others grew more slowly.

The big brute destabilizes the system. It more or less stays put, but its gravity slingshots the other cores to larger orbits. Two or three end up in elliptical orbits that average 15 to 20 AU from the sun. As they plow through small planetesimals in the outer disk, their orbits become circular. The cores accrete small amounts of gas and migrate out to about 20 and 30 AU respectively, the approximate distances of Uranus and Neptune. Thirteen of the 24 simulations produced solar systems similar to ours.

Critics point out that the model doesn't include the effects of gas drag in the disk, and there's no way to know if four or five cores formed between 5 and 10 AU. "It's clear that our level of sophistication of studying planet formation is relatively primitive," concedes Duncan. But he adds, "So far it's been very difficult for anybody to come up with a scenario that actually produces Uranus and Neptune." — R. N.

Near-Earth Asteroids Not That Big a Threat

Everyone can breathe easier: Armageddon isn't as close as astronomers thought. NASA scientists taking a census of large asteroids in Earth's neighborhood have cut their estimate to between 500 and 1,000 — half of what they previously believed. The new calculation comes from observations by NASA's Near-Earth Asteroid Tracking System (NEAT), which scans the sky with an advanced camera mounted on a 1-meter telescope in Hawaii. In the January 13 *Nature*, NEAT co-investigator David Rabinowitz of Yale University and his colleagues report that 322 near-Earth asteroids bigger than 1 kilometer (0.6 mile) in diameter are now known, a major chunk of the updated total population. While stressing that we need to learn more about potential hazards, Rabinowitz reassures: "None of the asteroids we've observed will hit Earth anytime in the near future."

KAIT Smashes Supernova Record

The Katzman Automatic Imaging Telescope (KAIT) at the Lick Observatory in California discovered 40 nearby supernovae in 1999, smashing its 1998 record of 19. Before KAIT became operational in 1997, the Beijing Observatory in China held the record with 15. KAIT is a fully automated 30-inch telescope operated by the University of California at Berkeley. Computers monitor the weather, open the observatory dome, point and focus the telescope, take digital images of several thousand galaxies every three to five nights, and identify supernova candidates. Undergraduate students weed out false alarms and find any supernovae the computers might have missed. "Maybe we'll break 50 or 60 in future years, but this can't keep going year after year because there are only so many nearby galaxies, and we're finding most of the supernovae in them," says team leader Alex Filippenko of Cal-Berkeley.

Alex Filippenko, Weidong Li (UC Berkeley)

Supernova sleuths Weidong Li and Alex Filippenko have set a record with this 30-inch scope.

Help Point the Hubble Space Telescope

If this year's crop of presidential candidates doesn't exactly capture your imagination, then consider casting a ballot for your favorite celestial object. The Hubble Heritage Project is soliciting your vote for an object to observe with the telescope. Astronomers Forrest Hamilton, Christian Luginbuhl, and Keith Noll will select the winner based on the vote tally as well as the object's scientific interest and potential for a compelling image. The target also must be one Hubble has yet to view. Votes will be accepted at the project's website at http://heritage.stsci.edu from March 21 to June 6, 2000.

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NOW WITH BAK-4 PRISMS!

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Newly upgraded with BAK-4 prisms for improved images. Multi-coated optics. Metal housing, not plastic. Tripod adaptable. Terrific price! Great gift.

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10x50 WA 7.0° field
Was $89.95 Now $79.95

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UltraView™ 50mm

Extra-long 22mm eye relief makes these superb for eyeglass wearers! Fully multi-coated optics, BAK-4 prisms. New twist-lock eyecups. Tripod adaptable.

7x50 6.5° field	$169
10x50 WA 6.5° field	$169

LONG EYE RELIEF!

Mini Giant™ Binos

Compact astro binocs that show you the light! Fully multi-coated optics, BAK-4 prisms. Long eye relief (8x56: 18mm, 9x63: 26mm). Easily hand-holdable, but also tripod adaptable.

8x56 5.8° field	$159
9x63 5.0° field	$189

TRIPOD L-ADAPTER INCLUDED!

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The most powerful truly portable binocular you can buy! Whopping 4.9" multi-coated front lenses of 625mm focal length (f/5). High-power images so bright, sharp, and resolved they'll knock your socks off! Rigid altazimuth fork mount features friction control on both axes, and allows pointing to zenith. Adjustable aluminum tripod. Weighs 24 lbs.

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32mm, 40mm	$59.95 each

.965"

6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm	$49.95 each

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.965"
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2.3mm, 21mm, 25mm	$119 each

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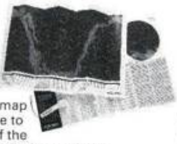

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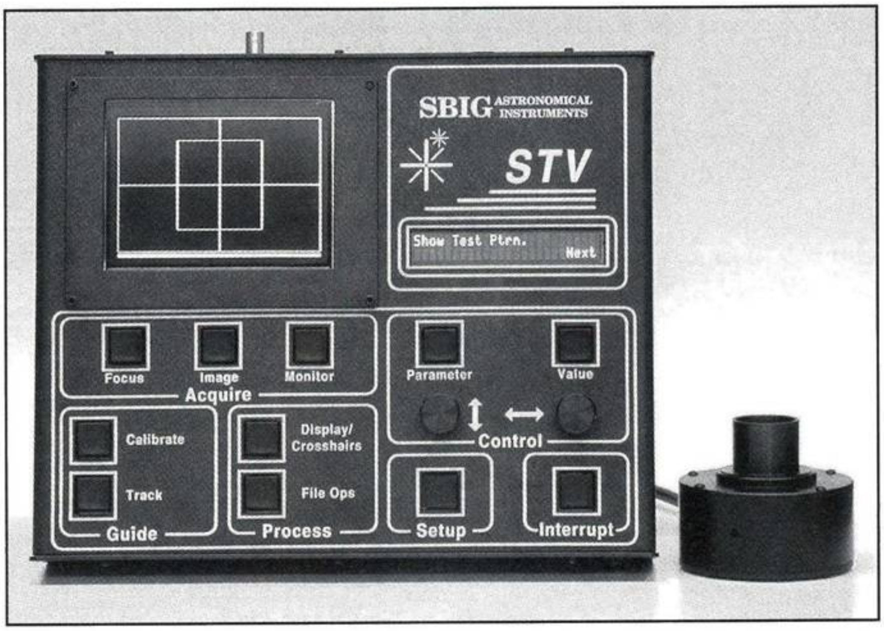
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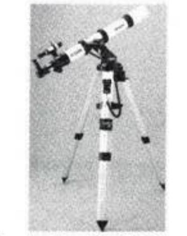

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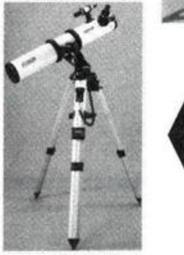

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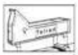

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Bursting the Bubbles

The Hubble Space Telescope has turned the study of planetary nebulae on its head.

by Adam Frank

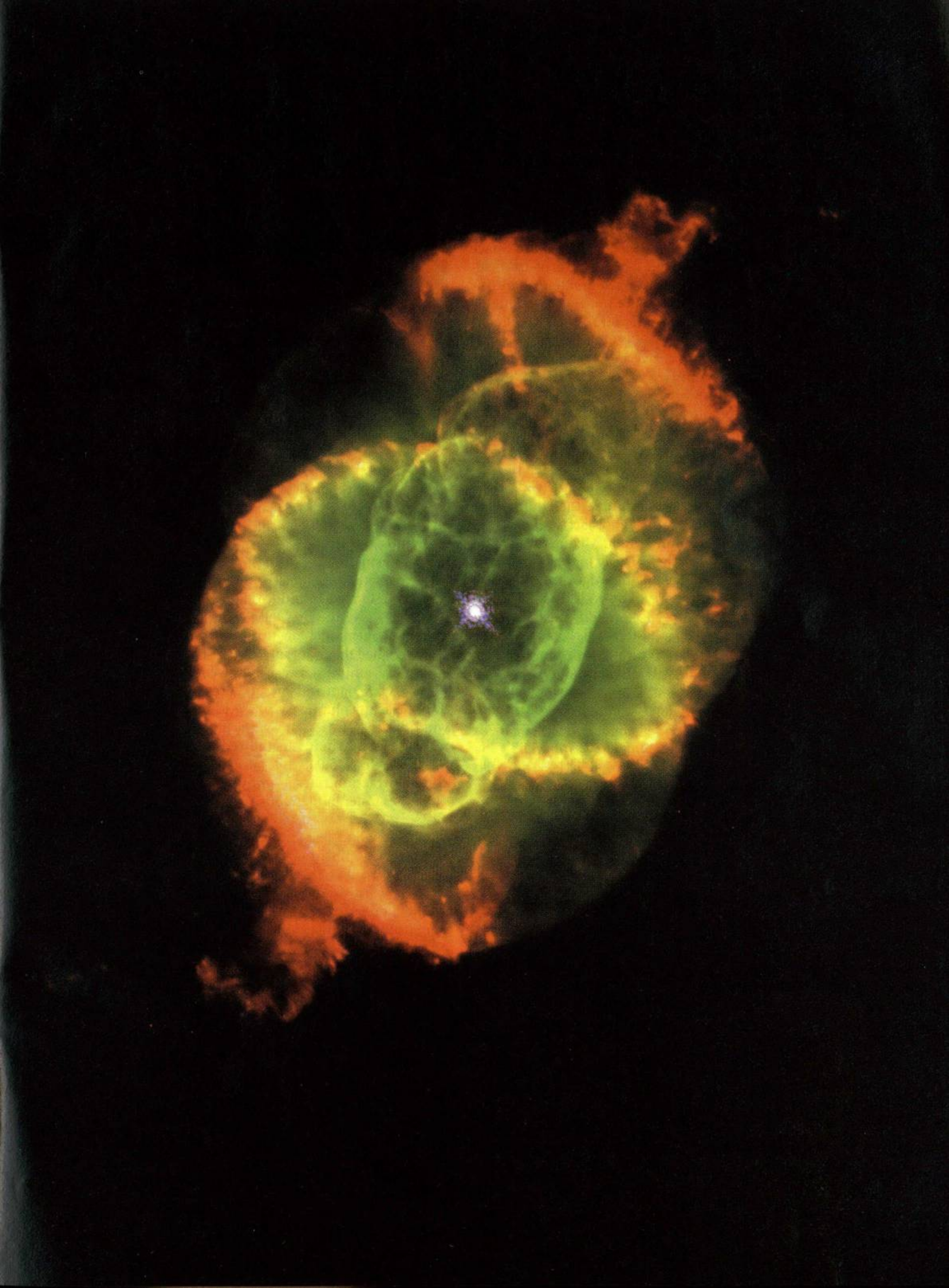
It's 7 A.M. on Monday. I'm flying at 30,000 feet above central Massachusetts on my way to Boston for the Second International Conference on Aspherical Planetary Nebulae.

As I write these words on the cramped airline fold-down table, astronomers like me, some coming from as far away as Israel, Australia, and Russia, are already converging at the Tang Center on the Massachusetts Institute of Technology (MIT) campus. We are gathering for a four day powwow to confer, consult, discuss, argue, and generally shake our collective heads in amazement.

Our science is pulling a fast one on us. Five years ago, I thought I understood planetary nebulae. I thought I understood how these luminous clouds of hot gas formed and what their shapes revealed about dying solar-type stars. Now all I know is that I understand very little. As my flight cruises toward Boston I find myself edgy with excitement. Our old ideas are being swept away, and we don't yet know what will take their place. Staring into that type of void offers a thrilling kind of vertigo for a scientist.

The Cat's Eye Nebula in Draco (NGC 6543) is a classic example of a point-symmetric planetary nebula. Every feature has an identical twin on the opposite side of the central star.

Patrick Harrington (University of Maryland), Kazimierz Borkowski (North Carolina State University), and NASA



Over the past 50 years astronomers have learned that planetary nebulae are gaseous gravestones marking the deaths of stars three-fourths to eight times the mass of the sun. Planetary nebulae are indeed the last gasps of stars similar to the sun.

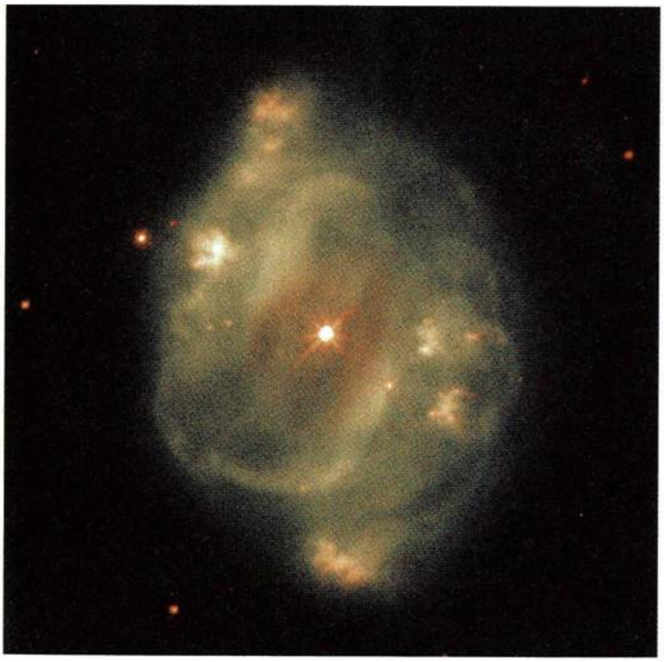
Until just a few years ago, many of us felt that we understood their shapes. With the best ground-based telescopes, planetary nebulae looked like circular smoke rings, sprawling ellipses, and vast figure eights. Based on these images, the community developed a theory that we were confident could embrace most or all of these shapes.

Then the spectacular resolution of the Hubble Space Telescope turned the smiles on our faces to looks of astonishment. Nature, as always, proved more creative than our imaginations could anticipate. As the images from Hubble revealed ever new forms and fine details — pinwheels, braided arcs, hourglasses, scalloped multipetaled flowers — our cherished theory got its back pushed to the wall. Something else is going on that we don't understand. This conference is our first collective opportunity to turn that unknown something into new science.

It's 8:30 A.M. when I walk into the arching glass atrium of the Tang Center. The space is large, airy, and buzzing with a hundred conversations and heartfelt greetings. I see the Old Hands, scientists who have met one another at conferences like this for the past 30 years. Next come the younger but established researchers such as me, who have been through this ritual enough to feel at home with it. Mixing through the crowd are postdoctoral researchers, newly minted Ph.D.s still working their way up the ladder. At the edges are the graduate students. Knowing few people, eager to learn and make a mark, this conference can be a mix of giddy adventure and terrifying ordeal. I remember it all too well. Fortunately, the community of planetary nebula researchers is an unusually rich blend of talented, enthusiastic, and genuinely kind people. I am happy to be in this collective company again.

The bell strikes 9 A.M. and we file into the auditorium to start the show.

Point-symmetric planetary nebula NGC 5307 in Centaurus superficially resembles a spiral galaxy.



Howard Bond (STScI), Robin Ciardullo (Penn State University), and NASA

All conference photographs by Graham Ramsay

Clockwise from top left: Susan Trammell, Raghvendra Sahai, Bruce Balick, Margaret Meixner.

Blowing Bubbles

Joel Kastner of the Rochester Institute of Technology, one of the conference organizers, presents us with a few words of welcome. He next introduces Sun Kwok of the University of Calgary to give the first talk. Kwok presents an overview of the dominant model for explaining planetary nebula shapes, our cherished theory of interacting stellar winds.

When a sunlike star reaches the end of its life, it first swells up into a red giant and later its core contracts to form a white dwarf. Each evolutionary phase is accompanied by a strong wind driven off the star's surface by either pulsation or the pressure of starlight. In the red-giant phase, the wind is relatively slow (45,000 miles per hour) and dense. In the hot-core-contraction phase a thousand years later, the wind is 100 times faster but tenuous.

In 1978, Kwok and his collaborators recognized that the fast wind would catch up with and smash into the red-giant material, sweeping it up into a dense shell just as a snowplow piles up snow. The pressure of the fast gas would push the shell outward like a giant wind-blown bubble. This bubble would appear as a round planetary nebula, such as the famous Ring Nebula (M57) in Lyra.

In 1987, my Ph.D. advisor, Bruce Balick of the University of Washington, generalized Kwok's idea to embrace all the planetary nebulae that did not appear round. Balick suggested that the slow red-giant wind might be expelled in a donut shape (a torus), dense at the equator and tenuous at the poles. The fast wind would be free to blow out perpendicular to the donut (i.e. through the central hole of the donut), but when it slammed into the thick walls of the donut, it would slow to a crawl, creating an hourglass (bipolar) shaped nebula.

In the first half of this decade, Balick and I, along with Vincent Icke and Garrelt Mellema of Leiden University in the Netherlands, constructed detailed computer simulations of this interacting-stellar-winds theory. The results were dramatic and proved the theory could reproduce the shapes of many planetary nebulae.

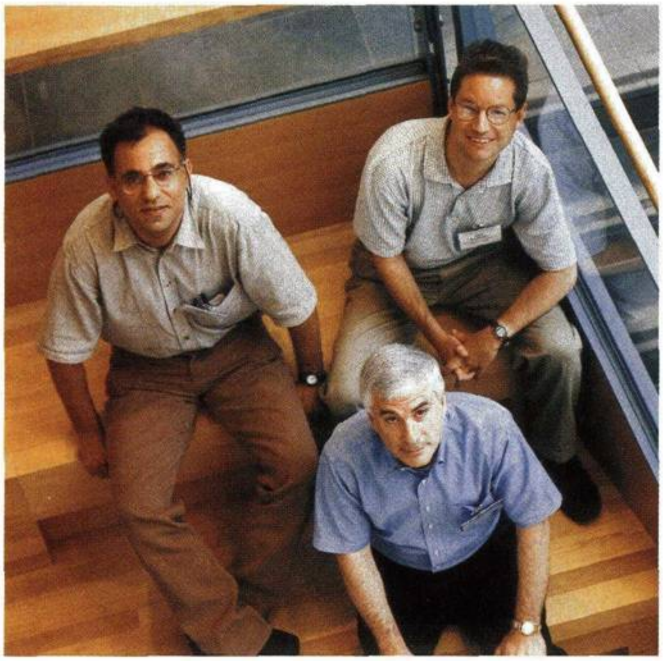
Kwok does a beautiful job reviewing the progress made with the generalized interacting-stellar-winds theory over the last decade. Then comes the question period. Hands shoot up. The action begins. Anyone who has ever been to an American Astronomical Society meeting with thousands of astronomers milling about knows it is a hard place to get science done. It is small gatherings like this one, with perhaps 100 participants, that research directions can be chosen and consensus forged.

These meetings are crucibles of science. Some people come to these meetings with a point to make, something they feel that must be recognized. Others take the skeptic's role, keeping the discussion close to the data and what is known. The debate following Kwok's talk centers on how effective the interacting-winds theory remains in the face of new Hubble images. The tone is polite but intense. All of us take this very seriously — it's not just our jobs, it's our passion. We really want to understand what is going on. Why do planetary nebulae have these wild, unexpected shapes?

Pinwheel Dilemmas

Next comes a string of talks focusing on new observations. Arturo Manchado and Romano Corradi from the Instituto de Astrofisica of the Canary Islands (a powerhouse of planetary nebula studies) each present new Hubble images that confound the interacting-stellar-winds theory. Many of the images show planetary nebulae with oppositely oriented jets of gas shooting out from the central star. In almost all cases the jets are not straight, but show a characteristic S-shape reminiscent of water from a spinning garden sprinkler. The S-shape is an example of point-symmetry — meaning every filament and blob on one side of a nebula appears reflected on the other side of a line cutting directly through the central star. A classic example of point-symmetry can be found in the Cat's Eye Nebula, where each feature has a corresponding twin on the opposite side of the central star. The specter of point-symmetry is destined to haunt our conference many times in the talks that follow.

The conference was organized by Noam Soker (left rear), Joel Kastner (right rear), and Saul Rappaport (front center).



From left to right: Noam Soker, Guillermo Garcia-Segura, Mark Morris, and Valentin Bujarrabal debate whether single stars can produce the extraordinarily complex shapes of many planetary nebulae.

Howard Bond of the Space Telescope Science Institute shows us NGC 5307, a point-symmetric jet so tightly wound that it looks more like a pinwheel galaxy than a planetary nebula. Raghvendra Sahai of JPL displays newly born planetary nebulae, where stars are just lighting up jetlike structures that already show point-symmetry. Point-symmetry can show up in images even when no jets are present.

I have run enough computer simulations to know that just making a jet is no problem for the interacting-winds theory. If the donut-shaped red-giant gas is dense enough, it acts like a nozzle, channeling the fast wind into extremely narrow jets. Making a point-symmetric jet is, unfortunately, another matter. The nozzle has to wobble like a top (precess) if the jet is going to trace an S-shape. But the donut is far more tenuous than cigarette smoke. Imagine trying to force a smoke ring to precess like a top — it would break apart and dissipate. That is why point-symmetry may be too much for the interacting-winds model to bear.

Talk Talk Talk

By mid-afternoon we are exhausted but wired on science and coffee. I'm always amazed by the stamina of my colleagues in their ability to talk science for hours on end. This can actually become a problem in the bars after the day's sessions end. "Can we please talk about something else!" is the oft-heard cry in the evenings.

As the coffee and cookies give us an energy surge, we continue laying the groundwork for a new understanding of planetary nebulae. One of the theories we consider comes from Mario Livio of the Space Telescope Science Institute. He gives a talk on the link between planetary nebula jets and accretion disks. Livio, an Israeli theorist who has long charted new directions in this field, is a fast speaker who punctuates his presentation with sweeping arm gestures. The accretion disks Livio describes are Frisbee-shaped disks of gas that form when matter tries to fall onto a star. The gas can end up

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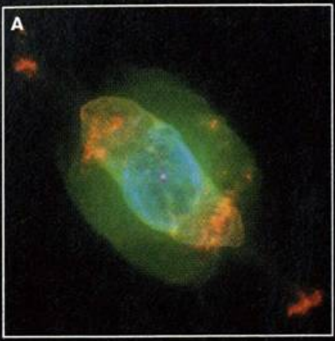

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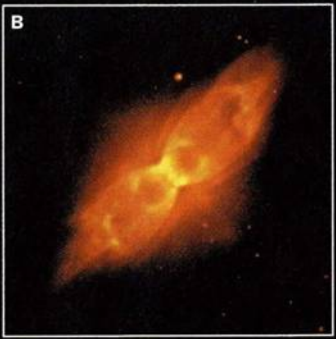

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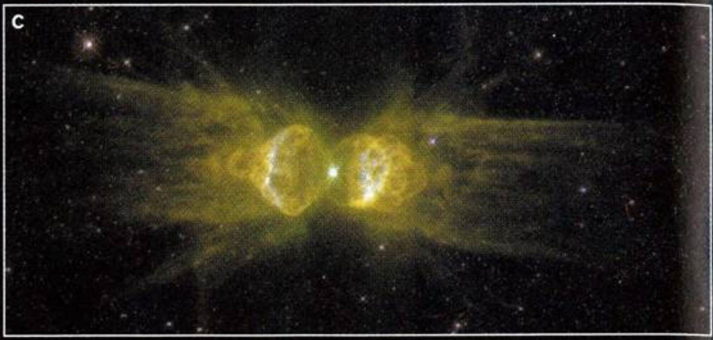

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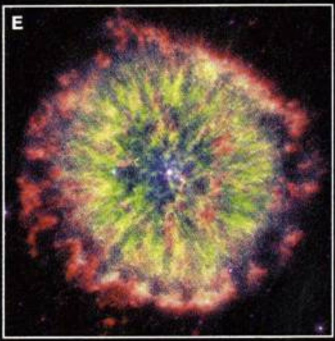

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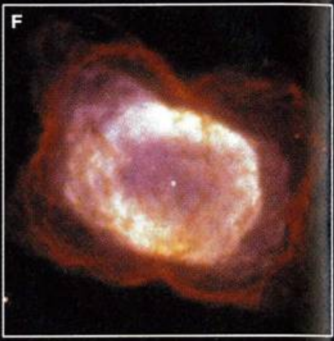

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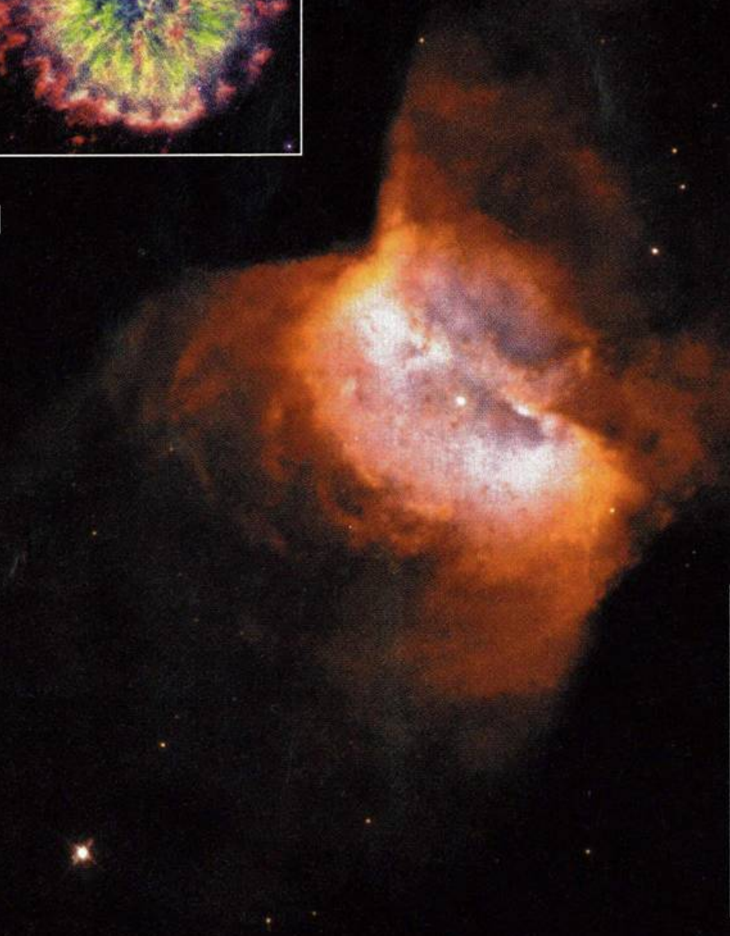

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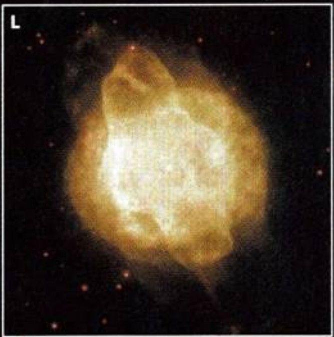

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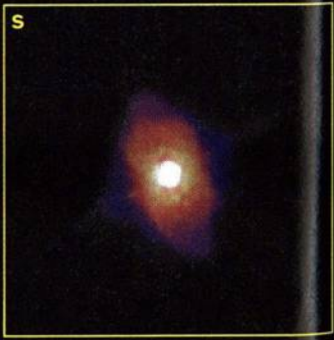
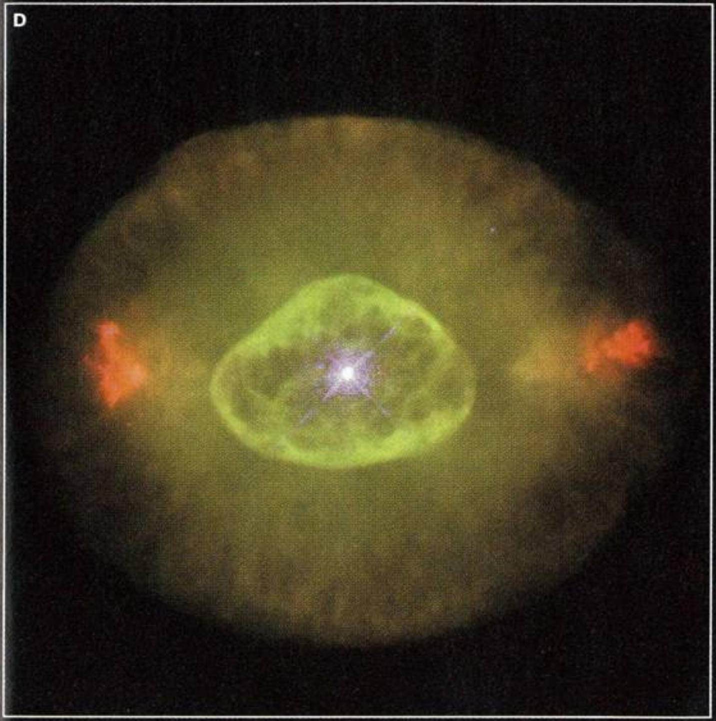
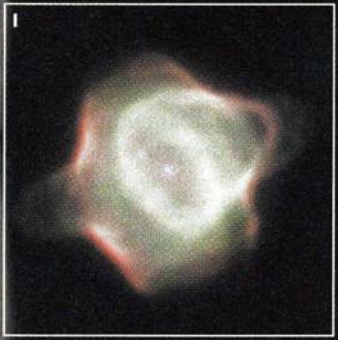


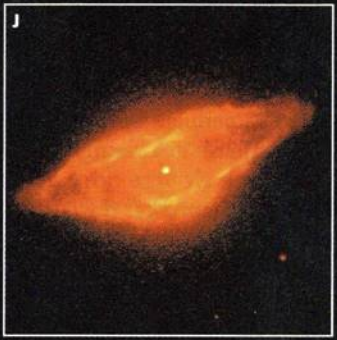
HUBBLE'S PLANETARY NEBULA GALLERY

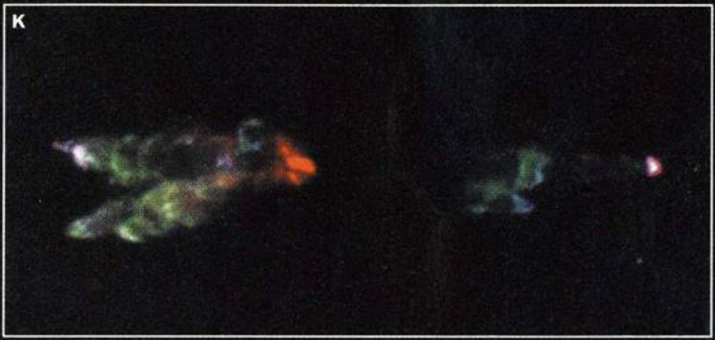
Planetary nebulae (letters A through P) have been known since the late 1700s. But it took the superior resolution of the Hubble Space Telescope to reveal these objects in all their glory. Planetary nebulae come in a bewildering variety of complex shapes, most of which theorists still don't fully comprehend. Astronomers study planetary nebulae to understand the late stages of stellar evolution, when stars like the sun throw off their outer atmospheres.

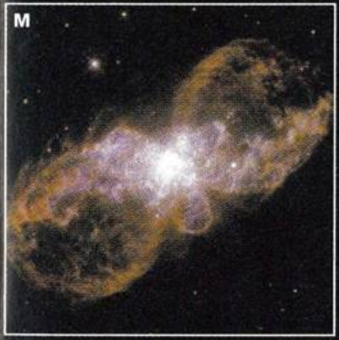
Protoplanetary nebulae (Q through V) represent the formative stages of planetary nebulae. The Hubble images shown here demonstrate that planetary nebulae acquire their complex shapes very early. The dying central stars of protoplanetaries are not yet hot enough to ionize the surrounding gas. Most of these images are not in true color.

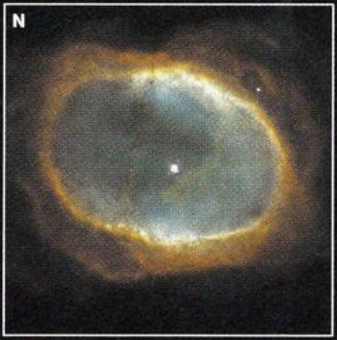


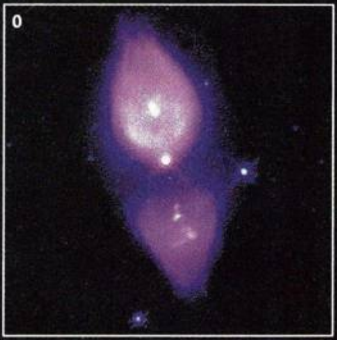


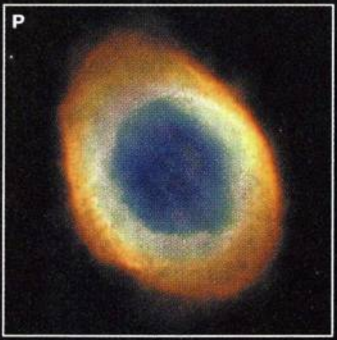


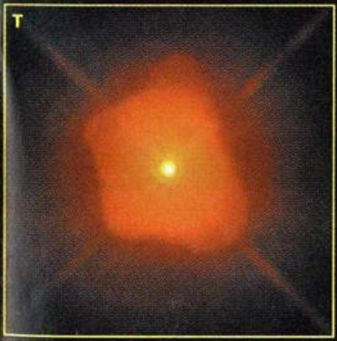


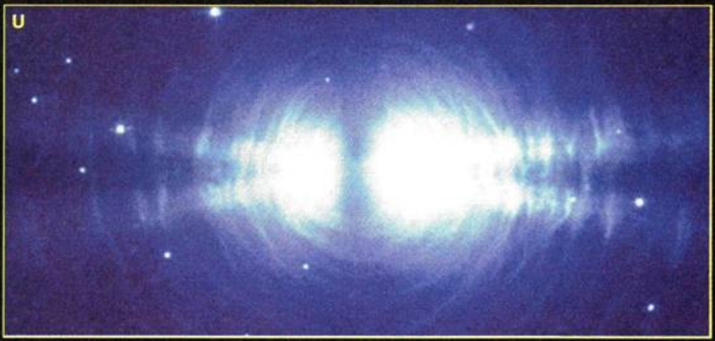


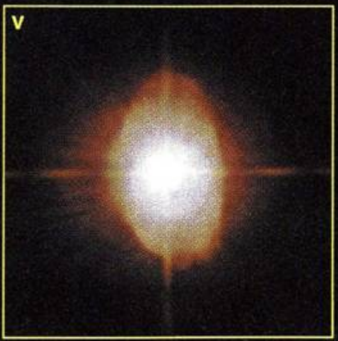












revolving around the star so quickly that centrifugal forces halt its further infall. The gas forms a disk, spiraling slowly inward toward the star via friction.

We already know that accretion disks exist around newly forming stars and black holes. In those settings we see jets shooting off in directions perpendicular to the disks. Supercomputer simulations have shown that magnetic fields can launch gas off a spinning disk and force it to flow in a narrow jet. Livio borrows these ideas and proposes that planetary nebula jets are born from binary star accretion disks. The accretion disk forms when matter spills from a larger star onto the smaller one. Magnetic forces in the disk then launch and focus a wind into a jet. Accretion disks also allow Livio to explain the troubling point-symmetry. He explains how gravity and radiation can knock the spinning disks off their rotation axes and set them wobbling like spinning tops. If the disk wobbles, so does the jet, and voilà, you have the garden-sprinkler effect.

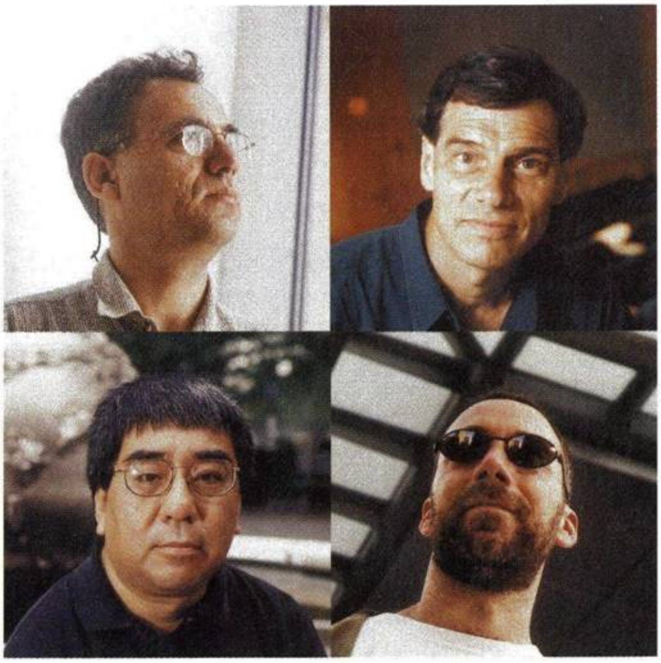
I listen closely to Livio's talk. It's an exciting idea. The use of accretion disks in planetary nebulae has been suggested before, the first time in a prescient paper by Mark Morris of UCLA in 1987. Since 1994, however, Livio and Noam Soker of the University of Haifa in Israel (one of the other conference organizers) have added more details to the picture, a crucial step in turning an idea into a full-scale theory. Later in the day Mauricio Reyes-Ruíz and José Alberto López of the Universidad Nacionale Autónoma de México (UNAM) add significantly to the accretion disk story by presenting new research showing how and when a disk might be created in a binary system. It is clear the scent of something important is being picked up.

On the subway back to my hotel, I look at the people around me and smile. It's a strange world. Lovers lean against each other, third-shift workers yawn, nighthawks stare at the ads above the doors. All these mundane details of life and yet somewhere a thousand light-years away there are mysteries staring my colleagues and me down. We made progress today but we are still in the dark.

Clues from the Beginning

Wednesday, 12 noon. This morning we explore a key piece of the puzzle. One of the most unexpected discoveries of the last five years is that the shaping of planetary nebulae occurs before they become planetary nebulae.

In our classic theory, the fast wind inflating the bubble comes from the hot, contracting star (it's the star's heat that drives the fast wind). But as Sahai, Kastner, Margaret Meixner of the University of Illinois, Susan Trammell of the University of North Carolina at Charlotte, and others demonstrate to us, planetary nebulae appear around cool stars, too. Somehow, stars that have not yet made their transition to the planetary-nebula phase are already producing jets and fast, hourglass-shaped gas flows. How is this possible? Without hot radiation, what is making the fast wind fast?



Clockwise from top left: Noam Soker, Mark Morris, Adam Frank (the author of this article), Sun Kwok.

The images make one thing clear — the nebula-shaping processes happens during the protoplanetary nebula phase. That, however, is our only firm conclusion, the rest is up for debate. After Meixner's talk, Sahai challenges her on exactly when protoplanetary nebulae show evidence for fast bipolar flows. Sahai believes that all planetary nebulae begin with jets carving cavities in the red-giant wind. Meixner holds fast to her belief that her Hubble images cannot yet support such a claim. They spar briefly in a pointed but respectful manner. This is the essence of science — competing viewpoints defining key issues of interpretation. I have a feeling that the Meixner-Sahai debate is one we will all repeat many times over the next few years.

The Great Debate

Thursday, 4 P.M. Over the last three days the questions have come into focus even if the answers have not. Now we gather for a formal discussion of the central issue: Can single stars produce aspherical planetary nebulae? The room is buzzing with anticipation. All talk of accretion disks and wobbling jets boils down to a reliance on binary stars. Binaries appear to be the first link in a chain of reasoning that leads to the fantastic shapes of most planetary nebulae. Perhaps this should not have come as a surprise. After all, at least half the stars in our Galaxy reside in binary or multiple systems. At the podium, the pro-binary team of Mark Morris and Noam Soker square off against the single-star advocates Valentin Bujarrabal of the Observatorio Astronomico Nacional Ministerio de Fomento in Spain and Guillermo Garcia-Segura of UNAM.

Preceding pages: A. NGC 7009 Bruce Balick (Univ. of Washington), et. al., and NASA **B. Henize 2–320** Raghvendra Sahai, John Trauger (JPL), and NASA **C. MZ–3** Sahai, Trauger, Balick, and NASA **D. NGC 6826** Balick, et. al., and NASA **E. NGC 6751** Arsen Hajian (USNO), Balick, et al., and NASA **F. NGC 7027** William Latter (SIRTF Science Center/Caltech), et al., NASA, ESA **G. NGC 2346** Hubble Heritage Team (NASA/AURA/STScI) **H. Minkowski 2–9** Balick, et. al., and NASA **I. Henize 1357 (Stingray Nebula)** Matt Bobrowsky (Challenger Center for Space Science Education) and NASA **J. Minkowski 1–39** Sahai, Trauger, and NASA **K. GL 618** Susan Trammell (Univ. of North Carolina at Charlotte) and NASA **L. NGC 3918** Howard Bond (STScI), Robin Ciardullo (Penn State Univ.), and NASA **M. Hubble 5** Balick, et. al., and NASA **N. NGC 3132** Hubble Heritage Team (NASA/AURA/STScI) **O. Minkowski 1–92** Trammell and NASA **P. M57 (Ring Nebula)** Hubble Heritage Team (NASA/AURA/STScI) **Q. IRAS 17150–32254** Toshiya Ueta, Margaret Meixner (Univ. of Illinois), Bobrowsky, and NASA **R. OH231.8+4.2** Latter, et al., NASA, ESA **S. IRAS 06530–0213** Ueta, Meixner, Bobrowsky, and NASA **T. IRAS 04296+3429** Sahai and NASA **U. CRL 2688 (Egg Nebula)** Sahai, Trauger, and NASA **V. IRAS 17436+5003** Ueta, Meixner, Bobrowsky, and NASA

Like me, Garcia-Segura is an astrophysicist who uses computer simulations. He has recently produced a series of beautiful simulations showing how magnetic fields embedded in the fast wind can produce extraordinarily narrow planetary nebulae without any need for a gaseous donut. This idea, first proposed by Roger Chevalier and Ding Luo of the University of Virginia, relies on hoops of magnetic energy acting like rubber bands to constrain the expansion of the bubble along the star's equator.

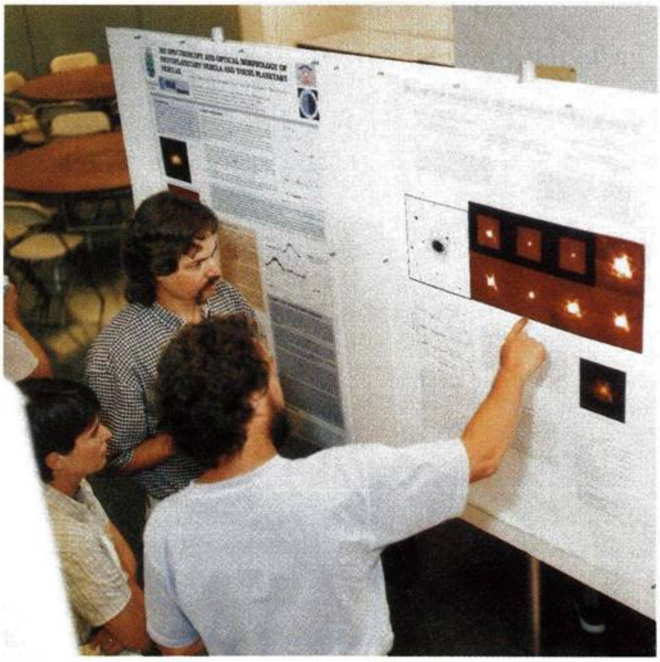
Based on their new simulations, Garcia-Segura and his collaborators claim that no binary stars are required to make jets and point-symmetric nebulae. For their idea to work, the single stars must spin rapidly enough to generate strong magnetic fields. I see great promise in their idea, but I am uncomfortable with the extreme strength of the magnetic fields their theory demands. I have already developed a bias for the binary point of view.

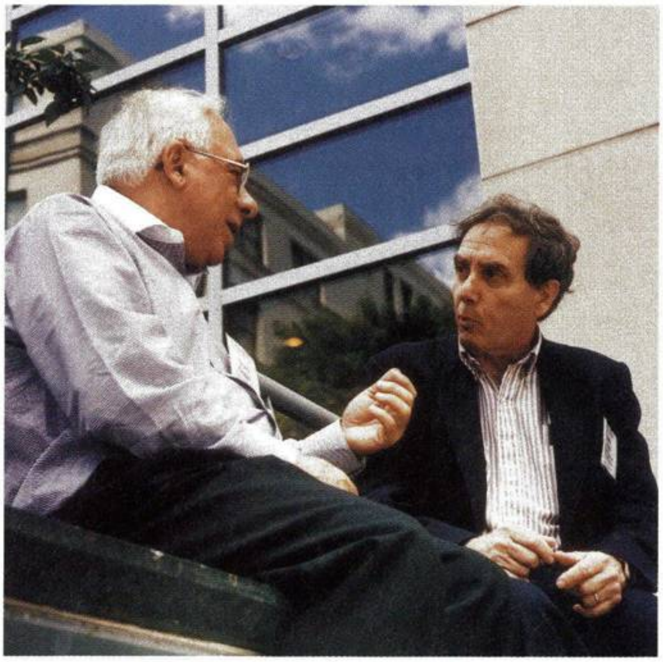
Yervant Terzian of Cornell University acts as moderator. It is a fitting choice because Terzian's graduate students and grand-graduate students (students of his students) populate planetary nebula science. Each speaker is given five minutes followed by rebuttals. Data and theoretical viewpoints are presented rapid fire. What evidence is there for binaries? What evidence is there for rapidly rotating single stars?

The high point comes when Noam Soker becomes a living simulation of winds and rotation. Beginning on a spinning stool with two Federal Express packages in his hands, he explains how fast rotation produced by a binary companion helps spur the ejection of the dying star's outer layers. The FedEx packages go flying. Then, still spinning, he pulls crumpled letter-sized envelopes from his pockets, demonstrating that whatever remains in a dying star's outer layers becomes the fast outflows seen in protoplanetary nebulae. It's a tour de force of comedic science — but with a point: Binary companions are probably needed to make bipolar planetary nebulae.

After the debate comes the conference banquet, a ritual of every scientific gathering. Some of the students slip away to go dancing or just hang out. I stay, filing into the MIT faculty club dining hall with the rest of my colleagues. Amazingly, after three solid days we are all still talking about planetary nebulae. The next round of Hubble observing proposals are due in just three weeks. Our heads are filled with new ideas for observation.

Small meetings such as the MIT planetary nebula conference allow astronomers to discuss their results in intimate settings.





Yervant Terzian (left), a patriarch of planetary nebula research, speaks with leading theorist Mario Livio.

Only as the dinner winds down does the conversation turn to personal matters. After years of working in a scientific field, colleagues can become cherished friends. These conferences may be the only time to catch up on marriages, births, jobs found, and positions lost. I am always taken aback by this part. We spend three days discussing objects tens of thousands of years old and trillions of miles across and yet still we are nothing more than people with desperately short lifetimes to connect to one another.

The Long Way Home

Friday, 5 P.M. I am on my way back to Rochester. I am exhausted but content with a mind that is full of new ideas and new research directions. While no definitive answers emerged from the conference, several themes were repeated enough times that perhaps we gained a sense of where we should be headed. Accretion disks, magnetic fields, early shaping during the protoplanetary nebula stage — now perhaps the waters are a bit less murky. Will a new paradigm for planetary-nebula evolution emerge from any of these elements? Only time, data, and our own ingenuity will tell. Is that discouraging? No way! The exploration of the unknown is, after all, what makes the trip, and science itself, such an adventure in the first place.

Astronomy *editorial advisory board member Adam Frank is an astrophysicist at the University of Rochester. His previous article for* Astronomy *was "Virtual Astronomy" in the August 1999 issue. His article "Blowin' in the Solar Wind" (October 1998) earned a science writing award from the American Astronomical Society.*

GALILEO'S DAUGHTER

Galileo's daughter, like his masterwork, was unsanctioned by the church, until she joined a convent.

by Dava Sobel

Most people know a simplistic story of Galileo's interaction with the Church. But what most people don't know is that his family and friends were official members of the Church and Galileo himself was a faithful believer. Forgotten aspects of Galileo's life, the everyday tasks and troubles of running a household as well as the historical episodes made famous over time, are made clearer to us in the letters written to him by his daughter, Sister (Suor) Maria Celeste. Her expressions and concerns place into perspective the events of the time as they lived them. Dava Sobel translates these letters, many never before seen, in her book Galileo's Daughter *and weaves them into an illuminating tapestry that tells the tale of the lives of a woman and her father.*

From the book, *Galileo's Daughter: A Historical Memoir of Science, Faith, and Love*. Copyright © 1999 by Dava Sobel. Reprinted by permission with Walker and Company. All rights reserved.

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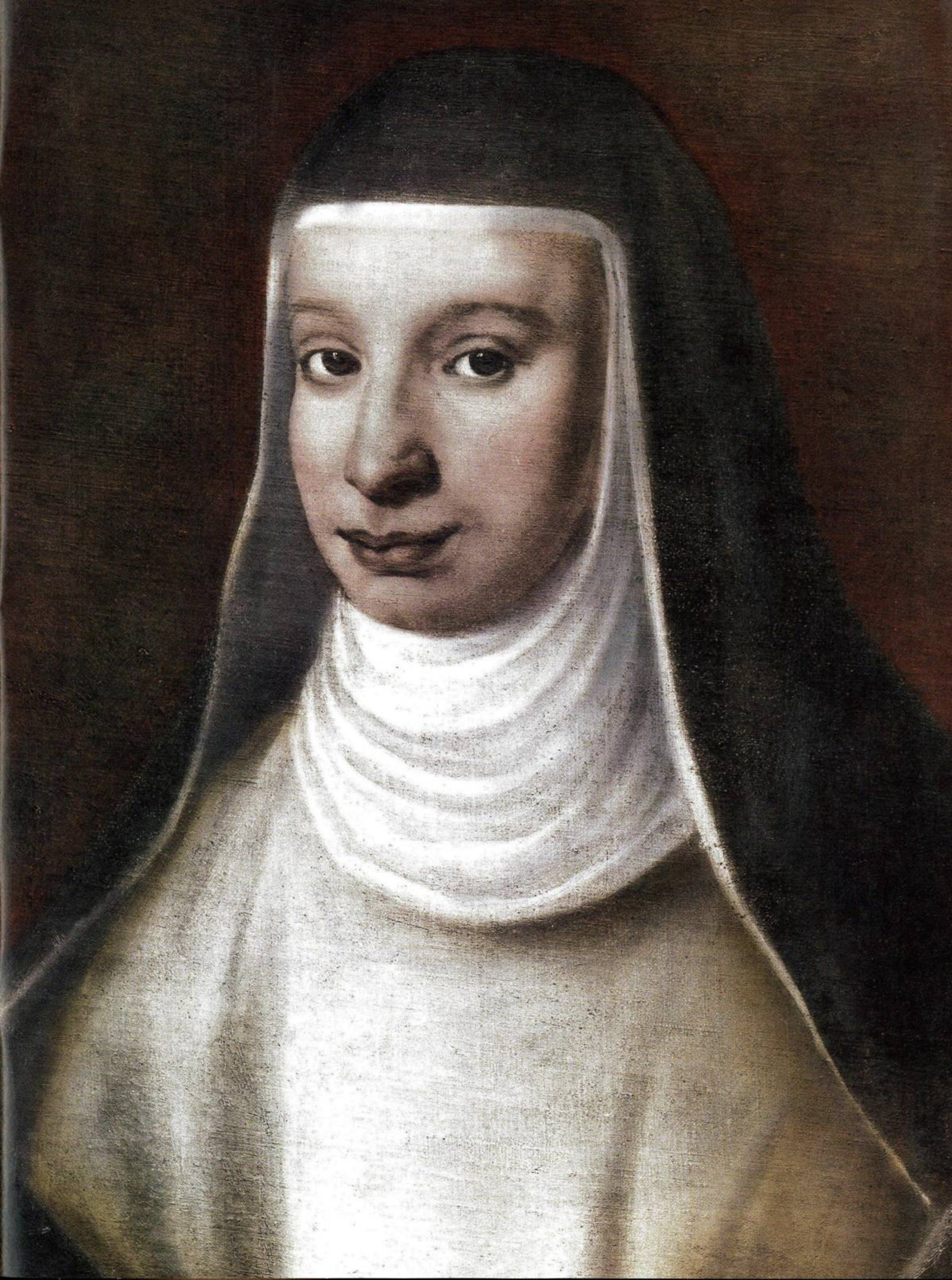


Galileo's daughter, born of his long illicit liaison with the beautiful Marina Gamba of Venice, entered the world in the summer heat of a new century, on August 13, 1600 — the same year the Dominican friar Giordano Bruno was burned at the stake in Rome for insisting, among his many heresies and blasphemies, that Earth traveled around the sun, instead of remaining motionless at the center of the universe. In a world that did not yet know its place, Galileo would engage this same cosmic conflict with the Church, treading a dangerous path between the Heaven he revered as a good Catholic and the heavens he revealed through his telescope.

Galileo christened his daughter Virginia, in honor of his cherished sister. But because he never married Virginia's mother, he deemed the girl herself unmarriageable. Soon after her thirteenth birthday, he placed her at the Convent of San Matteo in Arcetri, where she lived out her life in poverty and seclusion.

Virginia adopted the name Maria Celeste when she became a nun, in a gesture that acknowledged her father's fascination with the stars. Even after she professed a life of prayer and penance, she remained devoted to Galileo as though to a patron saint. The doting concern was only to intensify over the ensuing decade as her father grew old, fell more frequently ill, pursued his singular research nevertheless, and published a book that brought him to trial by the Holy Office of the Inquisition.

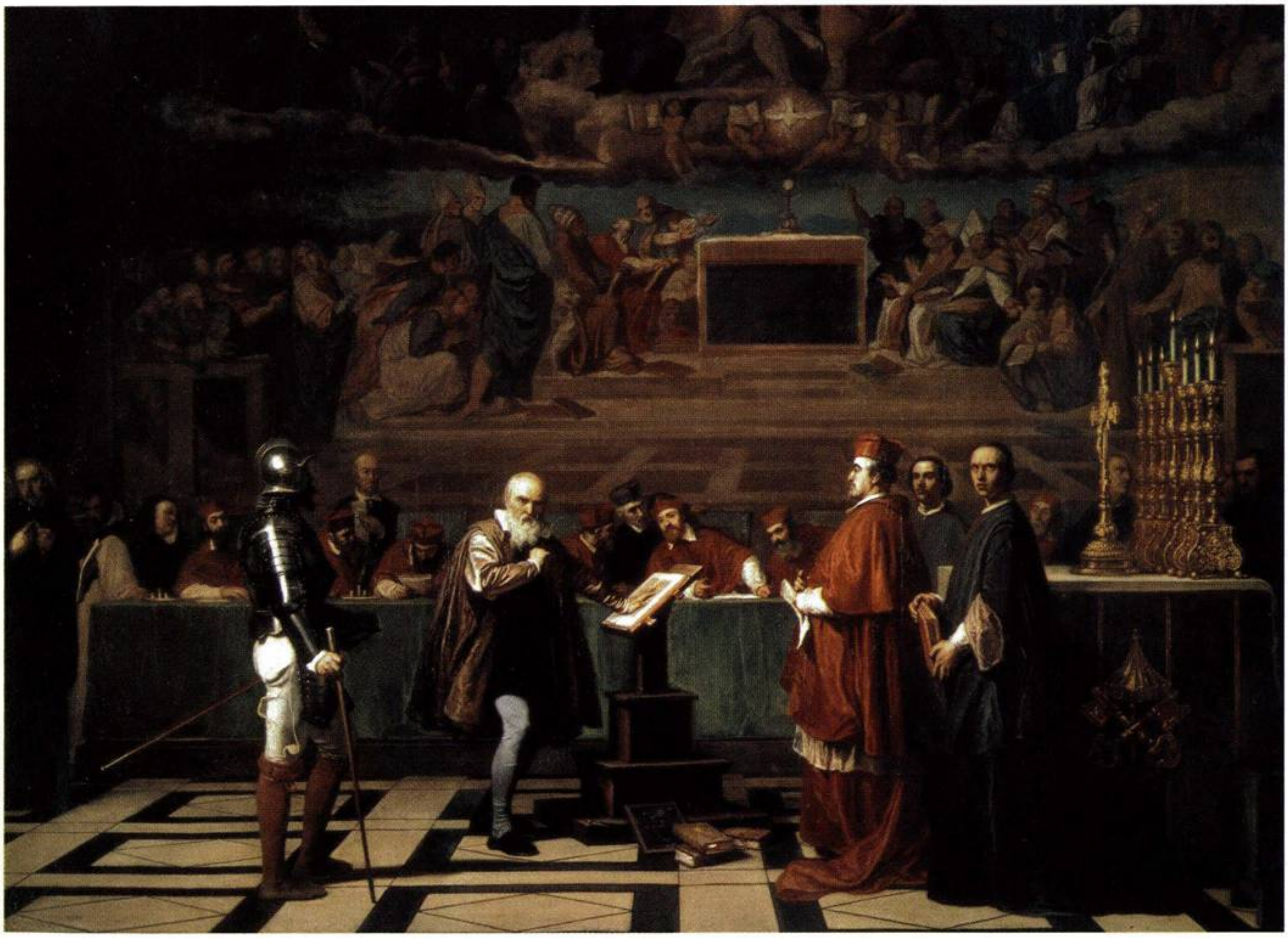
The "we" of Suor Maria Celeste's letters speaks for herself and her sister, Livia — Galileo's strange, silent second daughter, who also took the veil and vows at San Matteo to become Suor Arcangela. Meanwhile their brother, Vincenzio, the youngest child of Galileo and Marina's union, had been legitimized in a fiat by the grand duke of Tuscany and gone off to study law at the University of Pisa.

In 1609, when Suor Maria Celeste was still a child in Padua, Galileo had set a telescope in the garden behind his house and turned it skyward. Never-before-seen stars leaped out of the darkness to enhance familiar constellations; the nebulous Milky Way resolved into a swath of densely packed stars; mountains and valleys pockmarked the storied perfection of the moon; and a retinue of four attendant bodies traveled regularly around Jupiter like a solar system in miniature.

"I render infinite thanks to God," Galileo intoned after those nights of wonder, "for being so kind as to make me alone the first observer of marvels kept hidden in obscurity for all previous centuries."

In framing Galileo's trial as a simplistic case of science versus religion, anti-Catholic critics have claimed that the Church opposed a scientific theory on biblical grounds, and that the outcome mocked the infallibility of the pope. Technically, however, the anti-Copernican Edict of 1616 was issued by the Congregation of the Index, not by the Church.

In 1847, Robert Fleury (1797–1890) painted his version of what the trial of Galileo would have looked like. In reality, Galileo was tried and sentenced before a small number of individuals of the Holy Office of the Inquisition.



Musee de Louvre, Paris/SuperStock

Similarly, in 1633, Galileo was tried and sentenced by the Holy Office of the Inquisition, not by the Church. And even though Pope Paul V approved the Edict of 1616, just as Pope Urban VII condoned Galileo's conviction, neither pontiff invoked papal infallibility in either situation. The freedom from error that belongs to the pope as his special privilege applies only when he speaks as shepherd of the Church to issue formal proclamations on matters of faith and morals. What's more, the right of infallibility was never formally defined in Galileo's time, but issued two centuries later from Vatican Council I, held in 1869–70.

Although Urban personally believed in his own power enough to boast that the sentence of one living pope — namely Urban himself — outweighed all the decrees of one hundred dead ones, he refrained from claiming infallibility in the Galileo case.

> The injustice of the sentence tormented him so that he did not sleep for several nights but could be heard crying out, babbling and rambling in distraction.

Numerous churchmen — including highly placed clerics such as Ascanio Piccolomini, the archbishop of Siena — had endorsed Galileo's *Dialogue* from their initial reading of it and continued to consider the author their friend. "It seems exceeding strange to me," Archbishop Piccolomini had written to Galileo when the outcry over the *Dialogue* first arose, "that such a recent and precise approbation should be opposed by the passions of some people who might find fault only in what they conceive of the book, for the work itself ought to appease the most timid conscience. On the other hand, I will say you deserve this and worse, for you have been disarming by steps those who have control of the sciences, and they have nothing left but to run back to holy ground."

Archbishop Piccolomini, capping a long line of scholars from a distinguished family that produced two popes, had himself studied mathematics and been Galileo's admirer for many years. Now, in the aftermath of the trial, Piccolomini assumed custody of Galileo, who left the Tuscan embassy in Rome on July 6 and arrived at the archiepiscopal palace, immediately adjacent to the magnificent domed cathedral of Siena, three days later on July 9.

If Galileo looked "more dead than alive," as Ambassador Niccolini had described him when he returned from his April questioning by the Holy Office, how must he have appeared at Siena in July, after these many more weeks and traumas? The injustice of the sentence tormented him so that he did not sleep for several nights but could be heard crying out, babbling and rambling in distraction. The archbishop feared for his safety to the point where he considered binding Galileo's arms to keep him from accidentally injuring himself in bed. Piccolomini determined to restore the man's broken spirit and return his thoughts to scientific pursuits. The fact that Galileo was able to rise from the ashes of his condemnation by the Inquisition to complete another book project (and for this last work to prove his greatest original contribution) is due in large measure to Piccolomini's solicitous kindness. A French visitor to Siena in 1633, the poet Saint-Amant, reported finding the archbishop and Galileo together among the rich tapestries and furnishings that filled the guest apartment at the palace, engaging each other in discussion of a mechanical theory, which lay partially written on pages spread all around them.

Most Illustrious and Beloved Lord Father:

That the letter you wrote me from Siena (Where you say you find yourself in good health) brought me the greatest pleasure, and the same to Suor Arcangela, is needless for me to weary myself in convincing you, Sire, since you will well know how to fathom what I could not begin to express; but I should love to describe to you the show of jubilation and merriment that these mothers and sisters made upon learning of your happy return, for it was truly extraordinary; since the Mother Abbess, with many others, hearing the news, ran to me with open arms, and crying with tenderness and happiness; truly I am bound as a slave to all of them, for having understood from this display how much love they feel for you, Sire, and for us.

Hearing furthermore that you are staying in the home of a host as kind and courteous as Monsignor Archbishop multiplies the pleasure and satisfaction, despite the potential prejudicial effect this may have on our own interests, because it could well prove to be the case that his extremely enjoyable conversation may engage and detain you much longer than we would like. However, since here for now the suspicions of contagion continue, I commend your remaining there and awaiting (as you say you wish to do) the safety assurance from your closest friends, who, if not with greater love, at least with more certainty than we possess, will be able to apprise you of the facts.

But meanwhile I should judge that it would be wise to draw a profit from the wine in your cellar, at least one cask's worth; because although for now it is keeping well, I fear this heat may precipitate some peculiar effect: and already the cask that you had tapped before you left, Sire, from which the housemaid and the servant drink, has begun to spoil. You will need to give orders as to what you want done, because I have so little knowledge of this business; but I am coming to the conclusion that since you produced enough to last the entire year, and as you have been away for six of those months, you will still have plenty left, even if you should return in a few days.

Leaving this aside, however, and turning to that which concerns me more, I am longing to know in what manner your affair was terminated to the satisfaction of both you and your adversaries, as you intimated in the next to last letter you wrote me from Rome: tell me the details at your convenience, and only after you have rested, because I can be patient a while longer awaiting enlightenment on this contradiction.

Signor Geri was here one morning, during the time we suspected you to be in the greatest danger, Sire, and he and Signor Aggiunti went to your house and did what had to be done, which you later told me was your idea, seeming to me at the time well conceived and essential, to avoid some worse disaster that might yet befall you, wherefore I knew not how to refuse him the keys and the freedom to do what he intended, seeing his tremendous zeal in serving your interests, Sire.

Last Saturday I wrote to Her Ladyship the Ambassadress with all the great love that I felt, and if I receive an answer, I *shall share it with you. I close here because sleep assails me now at the third hour of the night, on which account you will excuse me, Sire, in the event I have said anything inappropriate. I return to you doubled all the regards you offered to those named in your letter and especially La Piera and Geppo, who are thoroughly cheered by your return; and I pray blessed God to give you His holy grace.*

From San Matteo, the 13th day of July 1633.
Most affectionate daughter,
S. M. Celeste

The deed that Signor Geri Bocchineri accomplished in Galileo's absence with the help of their young mutual friend, Niccolò Aggiunti, head of mathematics at Pisa, involved the destruction of potentially incriminating evidence. Fearing that representatives of the Inquisition might requisition Galileo's papers, his supporters took the prudent path of editing what could be found on his property.

Even though Signor Geri arrived at the convent in advance of Galileo's letter announcing his mission, Suor Maria Celeste surrendered her keys to him without hesitation. Geri served as a trusted link to her father throughout this period, and no one but her father could have informed him that she held the needed keys in safekeeping. These must have opened a certain closet or cabinet in Galileo's study. For surely Geri could have obtained keys to the gate and doors of the villa from Signor Rondinelli, who enjoyed free access to Il Gioiello, or from La Piera, the housekeeper, who would have opened any door to his familiar face — he being, as Vincenzio's brother-in-law, practically a member of the family. But only Suor Maria Celeste could help him unlock the trove of private papers.

Her description of the event shows she did not judge Signor Geri's action inappropriate, nor herself an accomplice to any crime against the Holy Office. Apparently nothing she — or Geri and Aggiunti, or Galileo — had done in this connection required asking God's forgiveness, or she would have shared her prayer for it here in writing, in her customary way.

Her description of the event shows she did not judge Signor Geri's action inappropriate, nor herself an accomplice to any crime against the Holy Office.

Her confusion about the contradictory outcome of Galileo's affairs in Rome — things appearing to her to have been settled to the satisfaction of both sides — stemmed from letters he sent just before being sentenced. At the end of May, as shown in surviving correspondence with his friends, Galileo fully expected leniency for himself and the saving of face for all concerned, though in the end nothing had turned out that way.

"I do not hope for any relief," Galileo wrote to a former pupil in France after the trial, "and that is because I have committed no crime. I might hope for and obtain pardon, if I had erred; for it is to faults that the prince can bring indulgence, whereas against one wrongfully sentenced while he was innocent, it is expedient, in order to put up a show of strict lawfulness, to uphold rigor."

Though the sisters of San Matteo had been overjoyed to

Galileo Recovers by Helping the Church

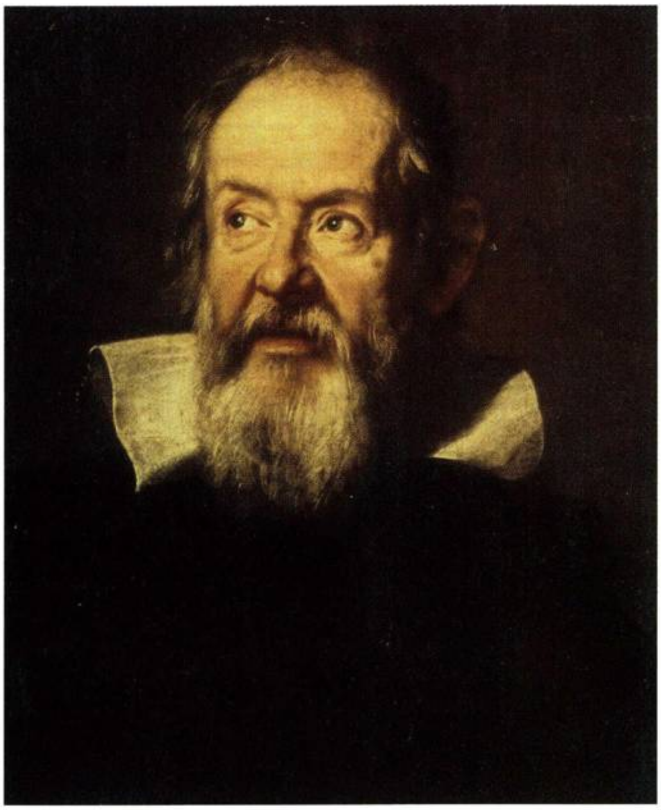
Galileo began to improve his health and outlook by engaging his mind in a new puzzle: Archbishop Piccolomini put him to work on the problem of recasting the giant bell for the cathedral's campanile.

Sienese foundrymen had erected the mold for the new tower bell out on the street, at the foot of the tall campanile with its many-windowed tiers. The mold consisted of two clay parts — one to sculpt the outer bell curve and one the inner — nested and resting upside down inside a huge scaffold. In order to maintain the crucial spacing between the two halves, the workers suspended the great weight of the inner mold across the rim of the outer by beams, like a sieve over a teacup. But when they started to pour the molten metal, the mold's inner section mysteriously rose and wrecked the contours of the resulting bell. Much surprise and speculation bruited through the piazza before Galileo offered the correct solution, which he proposed to reveal through a demonstration in the archbishop's home.

He called for an exact wooden model of the inner half of the bell mold, and when it arrived he inverted it and filled it with shot to make it heavy. Then he placed the mold model inside a glass urinal. The chamberpot cradled the bell mold, according to the archbishop's description, "leaving between the glass and wood a space the thickness of a piastra [a heavy silver coin]." Next Galileo began to pour mercury into the urinal through a hole near the top. As soon as the quicksilver climbed just a short way up the walls of the glass container, it lifted the shot-filled mold model — though the model weighed twenty times as much as the piddling amount of mercury underneath it. Galileo had predicted this effect on the basis of his early experiments with floating bodies, wherein he showed how even a small child might lift a heavy load merely by pouring a little water.

The same effect had undermined the casting of the bell, Galileo claimed: The liquified metal had quickly set the interior mold afloat, despite its great weight. On the next attempt, he counseled, the workers must tightly anchor the top handles of the inner mold to the pavement to prevent a recurrence.

"And thus," the archbishop was pleased to observe, "the second time, the casting went very well."
— D. S.


Erich Lessing/Art Resource, NY

This portrait of Galileo Galilei (1564–1642) was painted by Justus Sustermans (1597–1681).

hail Galileo's "happy return" to Tuscany from Rome, it soon occurred to them how far away from home Siena really lay. Not just the days' ride over forty miles of hilly terrain still barred the way of reunion, but the pope's anger as well. Galileo had not yet been granted permission to return to Arcetri. In fact, Urban might never allow him to go home.

"When you were in Rome, Sire," Suor Maria Celeste wrote Galileo on July 16, "I said to myself: if I have the grace of your leaving that place and coming as far as Siena I will be satisfied, for then I can almost say that you are in your own house. And now I am not content, but find myself longing to again have you here even closer. Be that as it may, blessed be the Lord for having granted us His grace so magnanimously until now. It falls to us to try to be truly grateful for this much, so that He may be the more favorably disposed and compassionately moved to bless us in other ways in the future, as I hope He will do by His mercy."

In Rome, Ambassador Niccolini continued to press for Galileo's return to Il Gioiello and notified him of each minuscule development in this campaign as a way of keeping hope alive.

Most Illustrious and Beloved Lord Father:

I read the letter you wrote to Signor Geri with particular pleasure and consolation, Sire, on account of the things contained in its first paragraph. I will be so bold as to venture on into the third paragraph as well, although it pertains to the purchase of some little house I do not know about, which I have inferred that Signor Geri very much wants Vincenzio to buy, albeit with your help. I certainly would not want to be presumptuous, interfering in matters that do not concern me. Nonetheless, because I care a great deal about whatsoever is of even minimal interest to you, Sire, I would implore you and exhort you (assuming you are in a position to be able to do this) to give them, if not the full amount, then some appreciable part of it, not only for love of Vincenzio, but just as much to keep Signor Geri favorably disposed toward you, as he has, on past occasions, shown great fondness for you, Sire, and, from all I have seen, tried to help you in any way he could: therefore, if, without too much trouble on your part, you could give him some sign of gratitude, I should judge that a deed well done. I know that you yourself can perceive and arrange such matters infinitely better than I, and perhaps I do not even know what I am saying, but well I know how anything I say is dictated by pure love toward you.

The servant who was in Rome with you came here yesterday morning, urged to do so by Signor Giulio Nunci. It seemed strange to me not to see letters from you, Sire. Yet I was appeased by the excuse this same man made, explaining that you had not known whether he would pass this way. Now that you are without a servant, Sire, our Geppo, who cannot move freely about here, desires nothing more, if only he were granted permission, than to come to you, and I should very much like that, too. If your thoughts concur, Sire, I could see to sending him well escorted, and I believe Signor Geri can secure him a permit to travel.

I also want to know how much straw to buy for the little mule, because La Piera fears she will die of hunger, and the fodder is not good enough for her, as she is a most original animal.

Since I sent you the list of expenses paid out for your house, we have incurred these others that I give you account of now, besides the money that every month I have made sure was paid to Vincenzio Landucci, for which I keep all the receipts, except the last two payments; for at those times he was, as he continues to be now, locked up in his house with the two little children because the plague killed his wife; whereby truly one may say she is released from her toil and gone to her rest, the poor woman. He sent early to ask me for the 6 scudi for the love of God, saying they were dying of hunger, and as the month was almost at its end I sent him the money; he promised the receipt when he is beyond suspicion of contagion, and I will endeavor to hold him to that; if nothing else I will first see to these other disbursements, in the event you are not here to take care of them yourself, Sire, which I suspect on account of the excessive heat that is upon us.

The lemons that hung in the garden all dropped, the last few remaining ones were sold, and from the 2 lire they brought I had three masses said for you, Sire, on my own initiative.

I wrote to Her Ladyship the Ambassadress, as you told me to, and sent the letter to Signor Geri, but I do not have a reply, wherefore I suppose I might be wise to write again suggesting the possibility that either my letter or hers has gone astray. And here, sending you love with all my heart, I pray Our Lord bless you.

From San Matteo, the 24th day of July 1633.
Your most affectionate daughter,
S. Maria Celeste

■

Dava Sobel is author of the international bestseller Longitude *and coauthor of* The Illustrated Longitude. *Her most recent book,* Galileo's Daughter, *was published by Walker and Company. Ms. Sobel resides in East Hampton, New York.*

the Seeker

The search for extraterrestrial life is the topic of Timothy Ferris's most recent endeavor.

Last fall, acclaimed science writer Timothy Ferris spoke with *Astronomy* about his PBS film, *Life Beyond Earth*, which aired on PBS in November. Ferris has written bestsellers that include *Galaxies*, *Coming of Age in the Milky Way*, *The Mind's Sky*, and *The Whole Shebang: A State-of-the-Universe(s) Report*. A member of *Astronomy*'s editorial board of advisors and a former editor of *Rolling Stone*, Ferris is author of more than 100 articles, essays, and reviews in such publications as *Esquire*, *Nature*, and *The New Republic*.

On a 5-kilometer stretch of highway in the Bonneville Salt Flats of Utah, Timothy Ferris illustrates just how brief the span of recorded history is. The highway represents the entire history of Earth (5 kilometers = 5 billion years), while the view through the magnifying glass is all of recorded history (the last 5,000 years). PBS, KCTS/Seattle

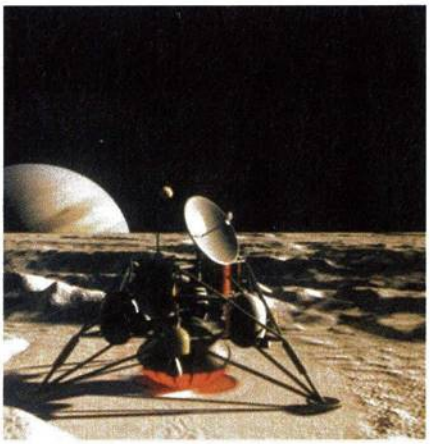
OMP

***Astronomy*:** Was the initial concept of *Life Beyond Earth* yours or did the producers contact you with the idea?

Ferris: When I did the *Creation of the Universe*, about 14 years ago, it was a very difficult process. I had to ask my wife to work on it and bail me out, otherwise we weren't going to get the desired result. She agreed on the condition that it didn't happen again. So I stayed out of filmmaking for over a decade.

When I turned 50, I began reflecting on the past. . . . I clearly wanted to accomplish more than could reasonably be done in the remainder of my life, unless I gave up something. I decided to stop teaching to make a couple more films, which also have an educational function. I don't agree with some of my scientist friends who think these films are solely entertainment. They are educational films, and I'm proud of that label. I don't shrink from it.

After I turned 50, I simply started telling people that I was back in the business of making films, if anybody wanted me. But having been out of it so long, I didn't have any contacts or friends who were filmmakers. Various producers did bring me ideas, but this was the first one that flew. The idea wasn't mine. I'm told the subject of life elsewhere is of the greatest interest to those who are outside of science. It is a very interesting way of looking at the universe, and one that Carl Sagan had always invoked. That's why I dedicated this film to Carl. He's certainly the figure in our time who is most identified with doing astronomy through the lens of looking for life.



This lander on Jupiter's moon Europa will melt surface ice and send a hydrobot to explore the ocean below. NASA/JPL, PBS, KCTS/Seattle

***Astronomy*:** You were the writer and narrator, but did you have creative control and is the finished product what you envisioned?

Ferris: Yes, I won't do a film without control. So aside from budget considerations and the luck of what works and what doesn't, the film is what I wanted.

***Astronomy*:** Are there one or two main ideas that you want people to come away with after watching *Life Beyond Earth*?

Ferris: I never think about that because, for some reason, I don't think about the audience in any of my work. If I were to encapsulate it, I'd say the reason why the subject of extraterrestrial life has become one of intense current interest is because of recent scientific findings that increase the reasoned probability we'll find it. Those include, most importantly, the discovery of extremophilic life — life in conditions of intense heat and cold — but also a long list of other findings such as extrasolar planets and so forth. The real engine that drives the fascination with this field right now is the realization that life can thrive and could indeed have begun in the dark, underwater, in situations that really hadn't been contemplated much before by biologists.

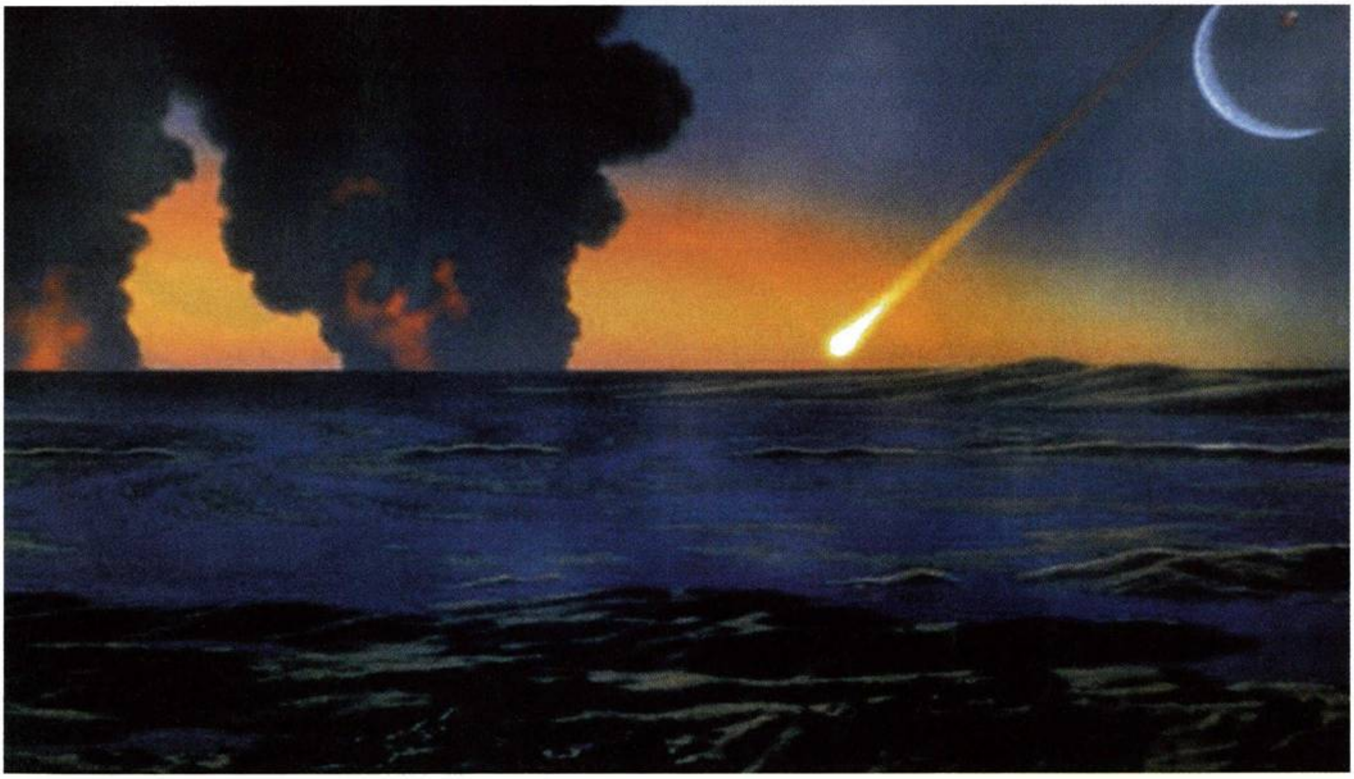
***Astronomy*:** The film makes people think, especially at the end where you ask the viewer what he or she would say to ET.

Ferris: The show's website (http://www.pbs.org/lifebeyondearth) encourages visitors to submit a letter they might write to an alien. The exercise encourages you to think about who we are. I suppose the end result in the search for life beyond Earth is that we can't know who we are until we know who they are.

***Astronomy*:** How might we find the first evidence of extraterrestrial life?

Ferris: To me, the searches for life are like wildflowers in the field — the more the

Earth's early history was dominated by volcanic eruptions and impacts. PBS, KCTS/Seattle



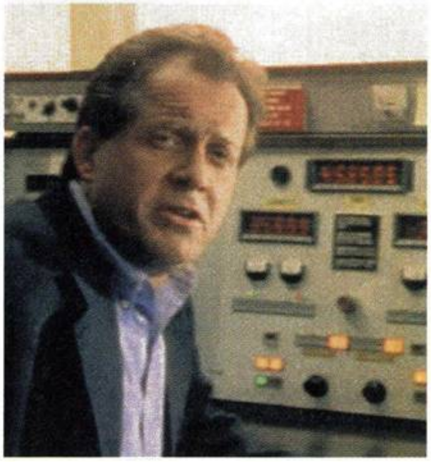
better — precisely because we don't know. When you don't know, the best thing is to try every reasonable search method, meaning ones that seem to have promise but don't blow your budget. The one method that we know doesn't work is doing nothing because we did nothing, for over 10,000 years, and we didn't find any life. This has created a predisposition to think that there isn't any life out there. If you and I had this conversation 10 years ago, you would have been able to cite relatively few methods of searching. Now there are more, and I hope that proliferation continues.

***Astronomy*:** Primitive life on Earth exists in an amazing variety of environments. Do you think extraterrestrial intelligent life will only evolve on planets similar to ours?

Ferris: That is the big question, isn't it? For just that reason the film is divided into two hours, the second of which is concerned with intelligence. The origin of life and the origin of intelligence are the two great mysteries of this subject. We know next to nothing about the origin of life, but we know a whole lot more about it than the origin of intelligence. It's just an amazing riddle, like the Taoist black bucket. The Taoists' image of contemplation is looking into water in a black lacquer bucket. You can see ripples in the water and you can see patterns that may or may not be projections of your own mind, but you can never see the bottom. So far, the origin of intelligence is like that. We don't know whether it's rare or commonplace, and we don't know how long it lasts when it appears.

***Astronomy*:** One of the film's most effective demonstrations was the Christmas tree, with lights blinking on and off symbolizing the rise and fall of technological civilizations. It shows how critical a civilization's lifetime is in this search. Unless civilizations can last a long time with respect to the age of the Galaxy, they're just going to be winking in and out of existence, and maybe only one would exist inside the Galaxy at a given time.

Ferris: Some of the most innovative sequences in the film resulted from informal conversations between director Linda Feferman and myself. The lobster scene was based on an essay I wrote years ago. I told her about it over lunch, and she said it would make a good scene. The Christmas tree was at the opposite extreme. We were quite late in production and had stopped all filming. We didn't have any money to do any more. Then Linda said she missed this point about time. She asked if there was a way to connect time and space to the search for life. We were sitting in the cafeteria at the TV station where the film was being edited. I drew the scene on the back of a menu, and we shot it in an unused sound studio at the station. It was really a last-minute affair, but it had an intriguing quality. It brought the total number of religious references in the film to three: Judaism, Islam, and Christianity.



Ferris asks viewers to contemplate what they would say in a message to ET. PBS, KCTS/Seattle

***Astronomy*:** There wasn't a lot of talk about religion in the film.

Ferris: It just didn't seem to me to be germane. In *The Creation of the Universe*, we had some overt religious references because religion is so tied up with people's concepts of cosmogony. Everything that happened to Galileo, as serious as it was and as damaging as its impact was on the Roman Catholic world, just pales compared to the virulence with which Darwin's work has been received. I try to keep reminding people that this is not really a conflict between religion and science. The vast majority of religious people are not involved in this. But those who are have certainly wielded an unreasonable amount of influence. Let me give you one example. We had applied for a grant from a new foundation for educational outreach. This would have made it possible to put, as we did with *Creation of the Universe*, a teaching kit and videotape in 100,000 science classrooms at a cost of $500,000. So it would have been $5 per classroom to make the film available as a teaching tool. This was a very important element of the project to me. We were turned down, and the person who informed me said that on the board of this particular foundation were, what he called, "Christians" and that they would not consider supporting such projects because the film discusses evolution. I guess quite a lot of this goes on, but it seems unfortunate to me. In the long run, people who bet against education are not doing themselves or their descendants any favors.

***Astronomy*:** Homo sapiens is the only species on Earth with some degree of control over its destiny. We're capable of many great things, but we also do great harm to each other and the environment that sustains us. Is intelligence, at least in human form, necessarily a good thing?

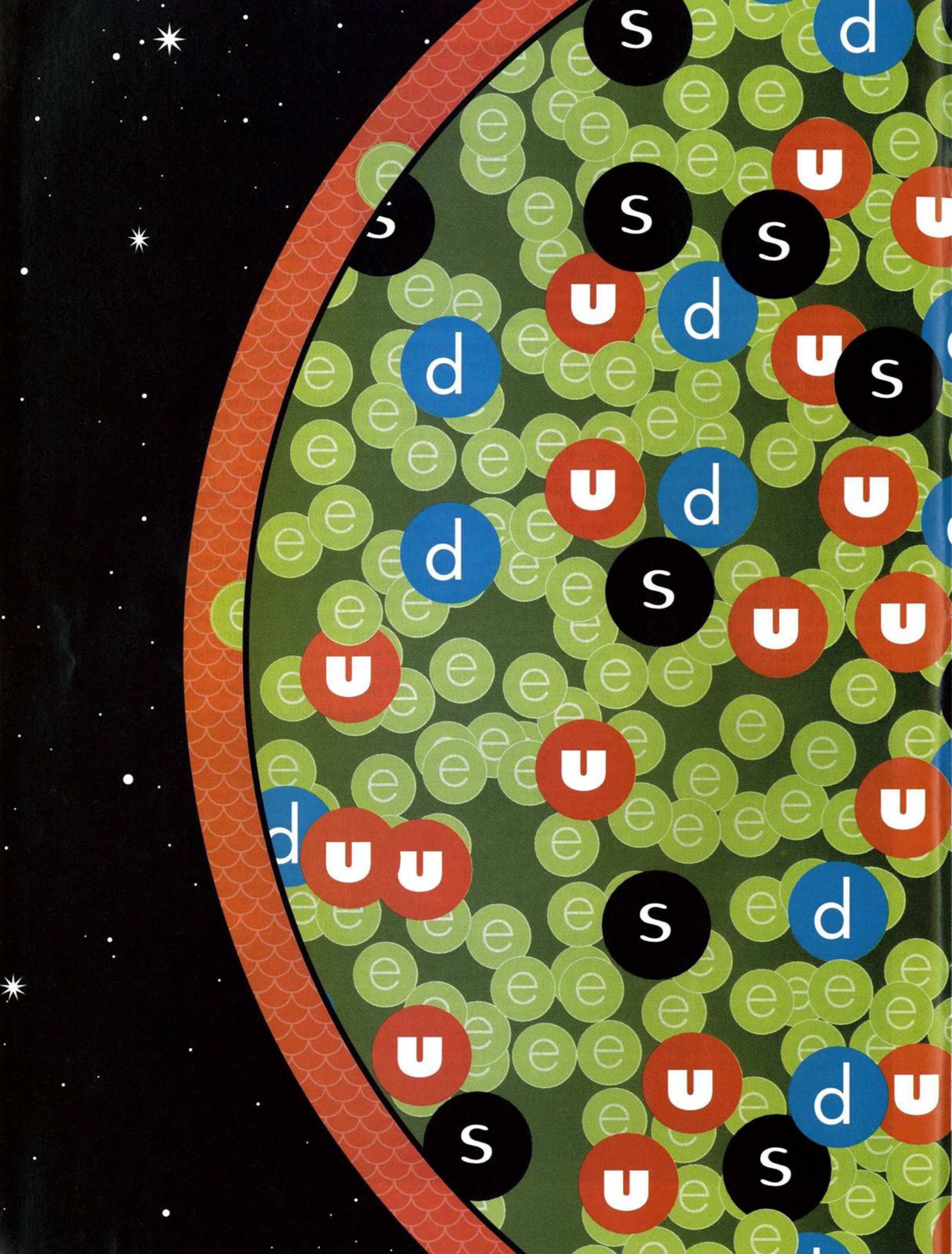
Ferris: To me, the issue is whether the universe is constructed in a way that will blossom into intelligence. Can a biosphere on a planet be expected to produce creatures that exploit its land, air, and water? That is one of the sad things about the conflict over evolution. I think both sides are under a misapprehension here. The religious fundamentalists seem to think there are inherently atheistic components to the theory of evolution, and some of my scientist friends seem to think so, too. But I just don't think that's the case. The answer to anyone who believes the universe is the manifestation of some sort of divine intelligence, or that it contains some deep level of design, is welcome to hold that opinion unopposed by the findings of science. We simply don't know. There is nothing in science, including evolution, which rules out belief in a deity. I don't happen to be a believer, but the conflict doesn't have to exist.

***Astronomy*:** What is your next project?

Ferris: I'm writing a book called *Seeing in the Dark* about stargazing. I'm interested in making a film of that book. It will be very different, with both extremes of scales but no middle. You have the vastness of the universe and the interior world of the eye and mind at the other end of the telescope, and nothing in-between. I've become fascinated by this hourglass-shaped dynamic: the infinite out there and the infinitesimal world within every person. So it's a film about those two universes, but I have to get the book written first.

***Astronomy*:** Do you have any idea when it might hit bookstores?

Ferris: I've conveniently forgotten the deadline. But I'd like to have it done in the next 2 or 3 years. I never can figure out how long it takes to do a book.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Hunting for the STRANGEST MATTER

A network of seismic sensors is turning our planet into a giant detector that just might find a bizarre form of cosmic shrapnel.

by Steve Nadis

Seismic monitors light up almost simultaneously along a line from Los Angeles to Boston. It can't be a normal earthquake because the subterranean disturbance, which registers 3.0 on the Richter scale, originates from a line, rather than from a point source. The cause — at least in this computer simulaton — is an errant piece of "strange matter," a fleck of cosmic shrapnel that pierces our planet at warp speed. While the existence of strange matter was proposed in 1971 by University of Illinois physicist Arnold Bodmer, physicists thus far have found no astrophysical evidence of it. But low-tech seismographs could change that.

Researchers at Southern Methodist University (SMU) in Dallas, Texas, are sifting through 13 years of seismic data this year in the hopes of finding earthly encounters of the strange-matter kind. It is just one of many approaches scientists have pursued in a decades-long search for this hypothetical material.

Unlike ordinary atomic nuclei — which consist of combinations of three "up" and "down" quarks confined to a single nucleon (either a proton or neutron) — strange-quark matter would be composed of a roughly equal mix of up, down, and strange quarks. In this state, nuclear particles are jammed together so tightly that quarks lose track of what nucleons they "belong" to and drift in a high-density gas.

Princeton University physicist Edward Witten suggested in 1984 that strange matter might be more stable than ordinary matter, meaning that it resides at a lower energy state. A tiny droplet of such material in the dense core of a neutron star would "eat" its way outward. The advancing material would convert regular matter into strange matter in less than 15 minutes — the so-called "Ice-Nine" scenario developed by University of Chicago physicist Angelo Olinto. The neutron star would swiftly become a strange star. The process might repeat in neutron stars in the universe.

An alternative, which deviates from the original strange-matter hypothesis, is that strange matter is more stable than ordinary matter, but only under extreme pressure. The outer portion of a neutron star, according to this theory, would be a thin crust composed primarily of neutrons. Under this layer, pressures would be great enough to create a core of strange-quark matter.

On the other hand, strange matter may not exist. Nevertheless, scientists continue to look for it, knowing that the discovery of a new kind of nuclear matter would have profound implications for physics and cosmology.

Many cosmologists believe that within a microsecond of the Big Bang, before atomic nuclei formed, quarks roamed the universe freely. Strange-quark clusters (having at least the mass of a planet) that formed then might have survived, perhaps constituting a sizable portion of the universe's "missing mass." Although this form of dark matter has not been ruled out, Henry Crawford of the University of California at Berkeley says, "It would be essentially invisible." Given that a baseball-sized clump of strange matter would weigh more than a trillion tons, objects of planetary mass would be relatively small and thus would scatter little light. That would make any search extremely difficult.

Many strange-matter seekers figure the best place to find the stuff is in the cores of neutron stars. "Of course, we can't actually see the center of a neutron star, but we can rely on indirect means to catch a glimpse," explains University of Chicago astrophysicist Coleman Miller. "The star's mass, its maximum spin rate, and the way it cools depend on the interior composition." Studies of a neutron star's inner depths, adds Miller, "can help us understand extremely high-density environments, telling us about how the strong force (which governs quark interactions) operates and providing insight on the early moments of the universe."

Another approach involves waiting for strange matter to come to us. Collisions between neutron stars or strange stars would scatter strange matter in all directions. An occasional chunk might pass through Earth and possibly lodge somewhere. In the past two decades, scientists have searched fruitlessly for traces of strange quark matter in Earth and moon rocks, in meteorites, in seawater and lakewater, in a variety of other substances, and even in cosmic rays. The quest continues.

A stray bit of strange matter might jiggle seismic monitors as it plows through Earth, according to SMU scientists analyzing data collected at 1,000 or so seismic stations scattered around the globe. "The beauty of this approach is we don't have to dig up rocks," says SMU physicist Vigdor Teplitz. "All the data are here; we just have to play with it. A strange-quark nugget greater than a ton and traveling hundreds of miles per second would emit seismic waves as it cuts through Earth like a stone moving through water." Scientists could then look for an astronomical source, such as colliding strange stars, which might emit gamma-ray flashes, says Teplitz.

"Unfortunately, there are no good candidates at the moment," admits Jes Madsen, a strange-matter theorist based at the University of Aarhus in Denmark. Strange stars might be hard to spot from their radiation output, because a thin crust of ordinary matter, which would likely blanket the surface, could make a strange star indistinguishable from a neutron star. Still, he says, "All neutron stars could be strange stars or at least have some strange matter in their centers."

Perhaps the clearest sign of a strange star would be a superfast pulsar spinning 2,000 or more times a second. To spin that fast, a star would be extremely compact: gravitational and strong nuclear forces would keep it from flying apart, says Norman Glendenning, a theoretical astrophysicist at Lawrence Berkeley National Laboratory.

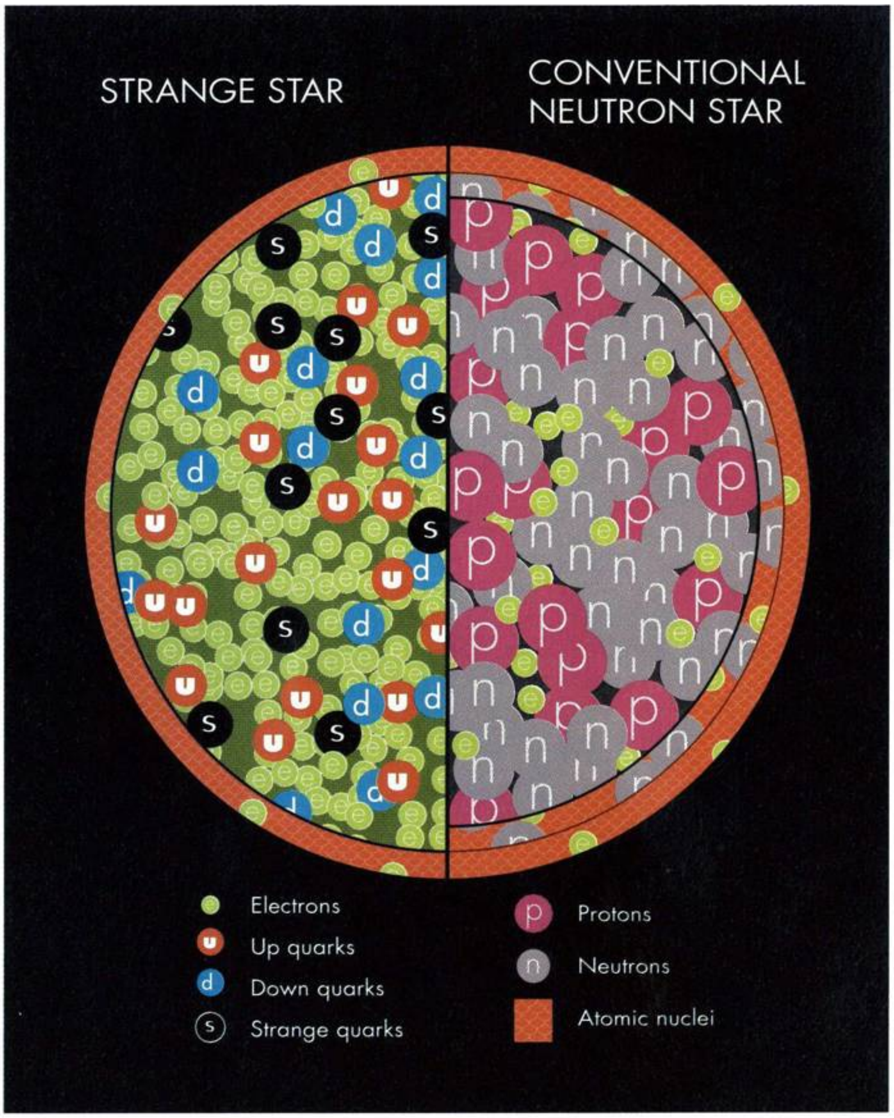
Another strange-star signature, says Massachusetts Institute of Technology physicist Robert Jaffe, would be "something less massive than you could get for a neutron star." A strange star with, say, one-tenth the mass of the sun would have a comparatively tiny radius, but nothing like this has ever been observed. "Nature doesn't seem to create pulsars that small," says Madsen.

A more promising avenue might be to explore the opposite extreme — neutron stars that seem to be too massive. "Neutron stars can't keep piling on mass indefinitely," explains Miller. At some point, the force of gravity would win out over the star's internal pressure and it would collapse into a black hole. "We still don't know what that limit is," he adds.

Miller and his colleagues developed a technique used by other astronomers to estimate that the neutron star 4U 1820-30 could have a mass about 2.3 times that of the sun, based on the rate at which material orbits it. However, 2.3 solar masses is "pretty big for a neutron star," says Olinto. "You could make a star that big with strange matter, which would be held together primarily by the strong force, not by gravity, and would therefore be better able to resist becoming a black hole." If neutrons alone can't do it, Olinto says, strange-quark matter is a possibility.

A strange star also might appear to be a neutron star that "spins down" more slowly than expected. An ordinary millisecond pulsar, Madsen explains, loses its angular momentum by emitting gravity waves. But a strange star would decelerate more slowly because the more viscous strange-matter interior tends to dampen the instabilities that lead to the emission of gravity waves. After about 1 million years, the rate of spinning of both neutron stars and strange stars will slow. "So it's easier to pick out the strange stars if you catch them early," says Madsen. "A millisecond pulsar with a supernova remnant — typically on the order of about 10,000 years old rather than 1 million years old — could bear the signature of a strange star."

Glendenning proposes a somewhat different scheme for identifying pulsars with strange-quark cores: looking for ones that mysteriously speed up before slowing down. In this scenario, a pulsar changes from a flattened pancake to a more spherical structure. Its central density increases under the force of gravity — perhaps crossing the critical threshold. Nuclear matter in the core would then convert to strange-quark matter, making the pulsar more compact and causing it to "spin up." Only isolated stars would be considered; otherwise gas and dust accreting onto a pulsar could increase the spin rate. The advantage of this method, Glendenning says, is that "no special observations are needed. After a new pulsar has been discovered — one can learn whether it's spinning up or spinning down." This effect would be most noticeable with millisecond pulsars, which are objects of considerable interest to astronomers anyway.



Astronomy/ Elisabeth Rowan and Frindolin Weber (Lawrence Berkeley National Laboratory)

Cornell University astronomer James Cordes confirms that a two-year pulsar survey now underway at the Arecibo Observatory in Puerto Rico is looking for exotic pulsars, extreme pulsars, and other fast-spinning objects. "If we find something unusual," says Cordes, "such as an isolated star that is spinning up, or pulsars that are extremely massive or very fast spinning, then we'll point an arsenal of telescopes at them, including the Compton Gamma-Ray Observatory and Hubble Space Telescope. If we don't see any objects like this, we won't be able to rule them out, but we will be able to set limits on their abundance."

While astronomers hunt for strange stars and other novelty items, physicists are pursuing a complementary tack — trying to make strange matter in the lab by creating "little big bangs." In accelerator experiments at Brookhaven National Laboratory, physicists collided gold nuclei to achieve densities 10 times greater than found in regular matter. The hope was to create a population of free quarks that might coalesce into a small lump of strange matter, a strangelet. The researchers are analyzing data from 10 million collision events to see if a strangelet candidate emerges. "Finding small strangelets in our accelerators would tell us about the stability of strange-quark matter," says Brookhaven astrophysicist Juergen Schaffner-Bielich. Meanwhile, Brookhaven scientists are planning to turn on a far more powerful accelerator next year, which should have an even better chance of producing strange matter.

As the Brookhaven team searches for strange matter amidst the wreckage of accelerator collisions, Teplitz and his SMU colleagues will be prospecting through earthquake data. Sorting through six million seismic reports is no small task, says Teplitz, who considers the job harder than finding needles in haystacks. The difficulty, in this case, is not knowing which haystacks to search, whether there are any needles in them, or whether the needles exist in the first place.

Success in these efforts could significantly change our view of nuclear matter and the forces that shape it. However, if the searches continue to find nothing, investigators may call off the hunt. Theorists would then be obliged to conjure up new models and postulate other exotic entities — some, perhaps, even stranger than strange matter itself. ■

Steve Nadis lives in Cambridge, Massachusetts, where he writes about astronomy and other strange matters.

THE SKY SHOW

Galaxies swarm in the spring sky, and the planets make for early evening targets.

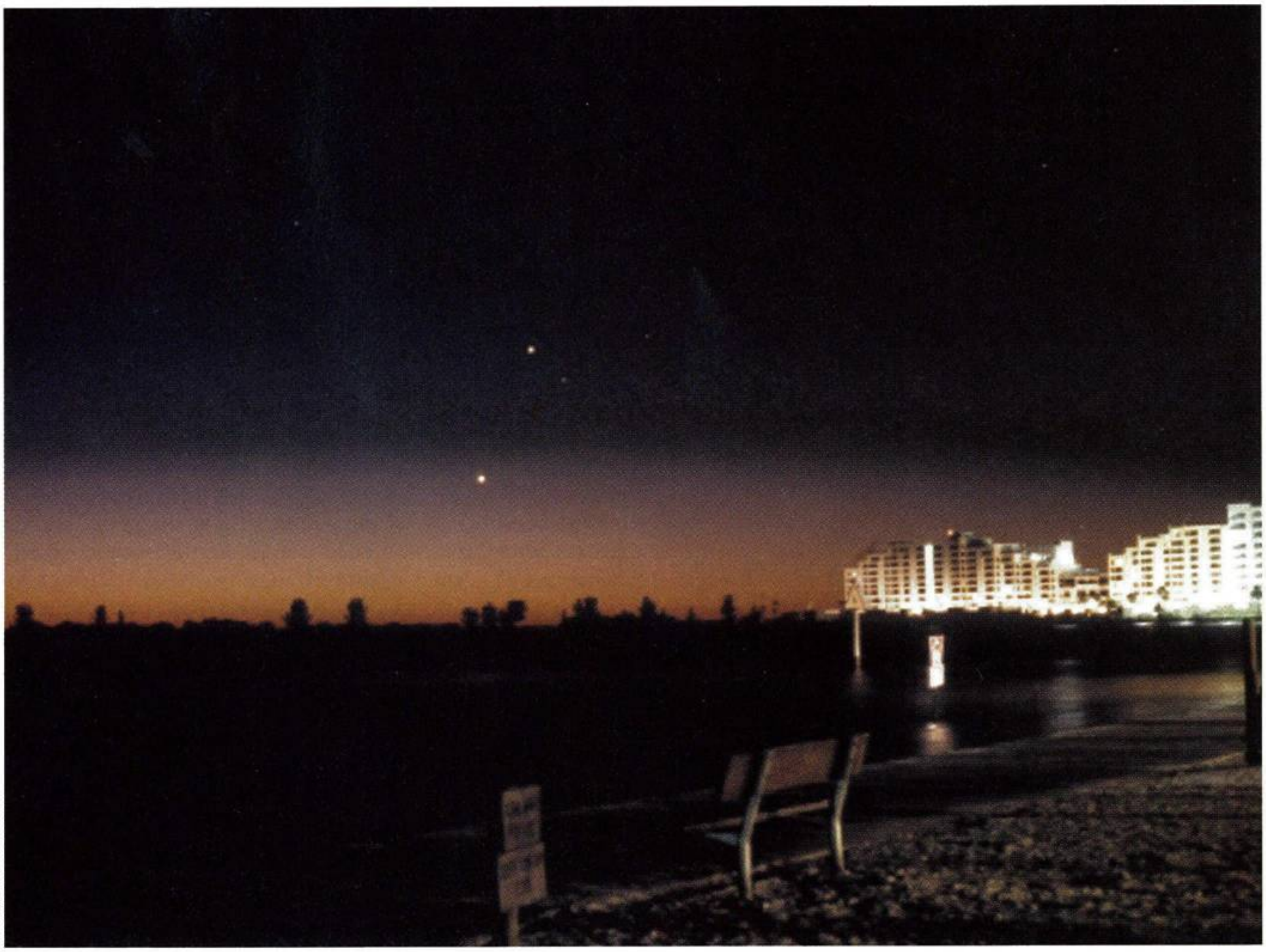
by Martin Ratcliffe and Alister Ling

▶ You'd be a fool this April if you didn't take advantage of the warmer weather and put in some extra observing hours. It still gets dark relatively early so that you won't lose precious hours of sleep. You can slip out into the backyard after supper and visit a number of planets, the galaxies of Virgo, and a nebula or two in the Milky Way and still get inside in time for the 10 o'clock news.

The planetary gathering at dusk reaches its best in April when **Mars**, **Jupiter**, and **Saturn** all lie within a 5° circle. Jupiter is the brightest and first to appear in the luminous evening twilight, shortly after sunset. Look west to find the three planets trailing in the sun's wake. Once you have located the planetary trio, check out their comparative brightnesses. Jupiter shines at magnitude –2.0, Saturn at 0.3, and Mars comes in at 1.4. High above, in Taurus, lies the magnitude 0.8 "eye of the Bull," Aldebaran. Its ruddy hue imitates Mars.

A mere 6° separates Jupiter and Saturn on April 1. On April 5, look for the very young moon entering the evening twilight scene — but don't wait too long because the moon quickly slips away, below the horizon. The following day, on April 6, Mars passes within 1.1° of Jupiter, with the growing crescent moon lying 3° south of Saturn. Jupiter and Saturn roll deeper into the twilight each night, but Mars appears to linger. On April 11, the three planets form a beautiful equilateral triangle, followed by Mars passing 2° north of Saturn on the 16th. The next time these planets become so close is 20 years from now, on March 26, 2020.

Before Jupiter and Saturn are lost in the solar glow of twilight, use your telescope to reveal their splendor — the fine belts and zones of Jupiter and its dancing retinue of moons, the delicate ring system around Saturn.



Glow along the horizon and the light pollution of the huge hotel and casinos of Atlantic City can't completely hide the splendor of Venus, Mars, and Jupiter.

Ken Rejko and Glenn Smith

APRIL 2000

2 The moon passes 1.6° south of Mercury, 8 A.M. EDT

3 The moon passes 3° south of Venus, 2 A.M. EDT

4 New moon is at 2:12 P.M. EDT

6 The moon passes 5° south of Mars, 6 A.M. EDT (page 66)
The moon passes 4° south of Jupiter, 7 A.M. EDT (page 66)
The moon passes 3° south of Saturn, 5 P.M. EDT (page 66)
Mars passes 1.1° north of Jupiter, 7 P.M. EDT (page 66)

8 The moon is at perigee (228,825 miles from Earth), 6:07 P.M. EDT

11 First quarter moon is at 9:30 A.M. EDT

14 Asteroid Massalia is at opposition, 4 A.M. EDT

16 Mars passes 2° north of Saturn, 7 P.M. EDT

18 Full moon is at 1:41 P.M. EDT

21 Lyrid meteor shower peaks

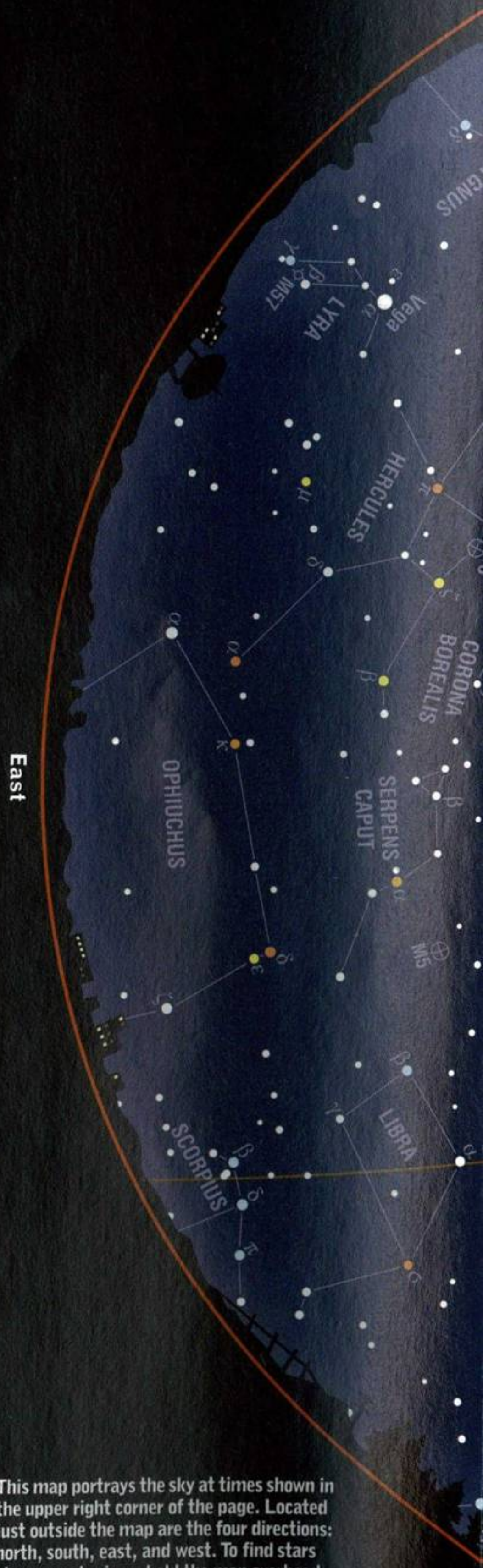
24 The moon is at apogee (251,381 miles from Earth), 8:26 A.M. EDT

26 The moon passes 1.0° south of Neptune, 2 P.M. EDT
Last quarter moon is at 3:30 P.M. EDT

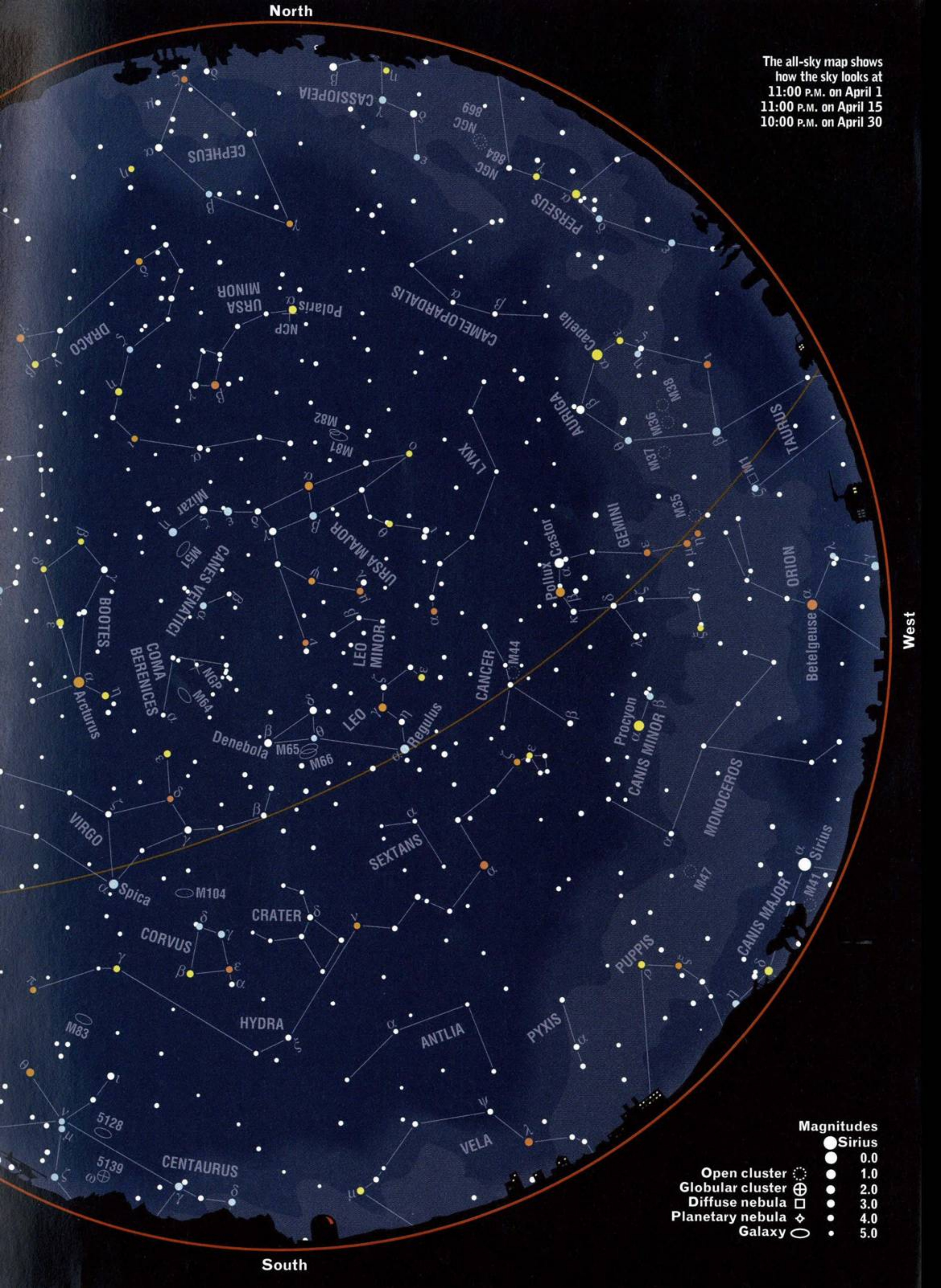
27 The moon passes 1.3° south of Uranus, 6 P.M. EDT

28 Mercury passes 0.3° south of Venus, 5 A.M. EDT (page 68)

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1 🌘
2 🌘	3 🌘	4 🌑	5 🌑	6 🌒	7 🌒	8 🌒
9 🌒	10 🌒	11 🌓	12 🌔	13 🌔	14 🌔	15 🌔
16 🌕	17 🌕	18 🌕	19 🌕	20 🌕	21 🌕	22 🌕
23 🌖 30 🌘	24 🌖	25 🌖	26 🌗	27 🌗	28 🌘	29 🌘



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


The all-sky map shows how the sky looks at
11:00 P.M. on April 1
11:00 P.M. on April 15
10:00 P.M. on April 30

North
South
West
CASSIOPEIA
CEPHEUS
NGC 869
NGC 884
PERSEUS
URSA MINOR
Polaris
NCP
DRACO
CAMELOPARDALIS
Capella
AURIGA
M38
M36
M37
TAURUS
M1
M82
M81
LYNX
Mizar
URSA MAJOR
CANES VENATICI
M51
GEMINI
M35
Castor
Pollux
ORION
Betelgeuse
BOOTES
Arcturus
COMA BERENICES
NGP
M64
LEO MINOR
CANCER
M44
LEO
Regulus
Denebola
M65
M66
Procyon
CANIS MINOR
MONOCEROS
VIRGO
Spica
M104
SEXTANS
CRATER
CORVUS
HYDRA
ANTLIA
PYXIS
PUPPIS
M47
Sirius
M41
CANIS MAJOR
M83
5128
5139
CENTAURUS
VELA
Magnitudes
Sirius
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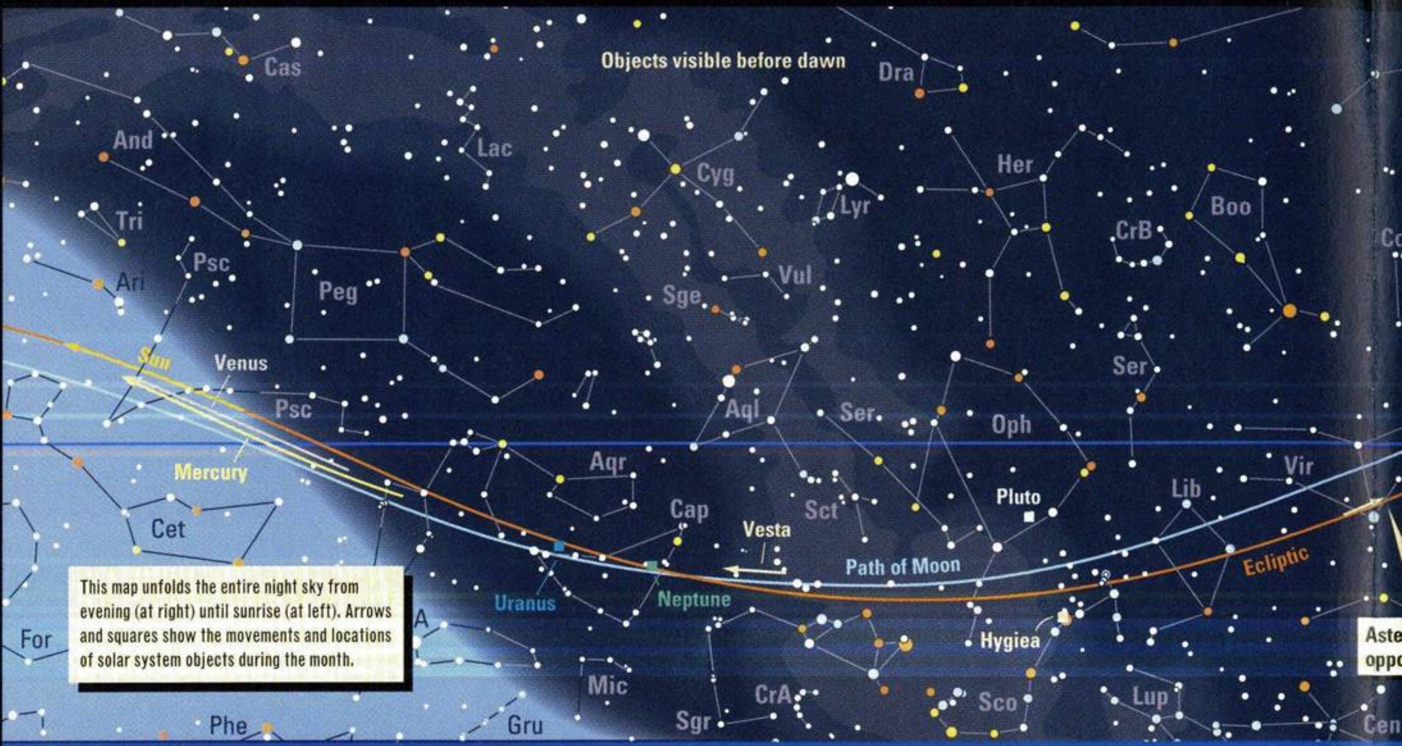
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Objects visible before dawn
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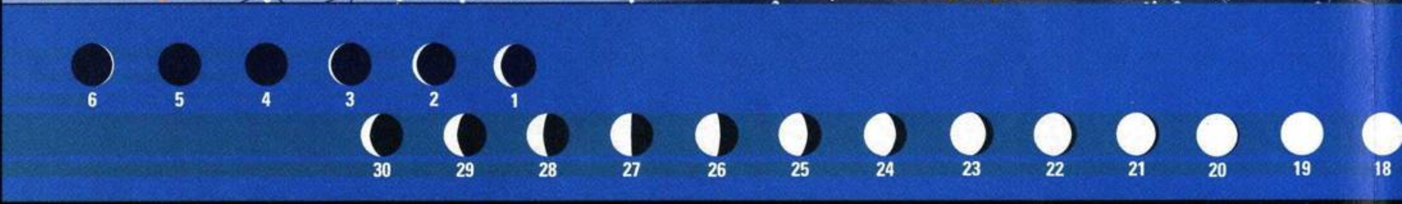
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.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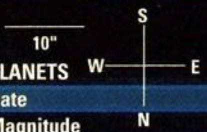
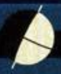
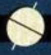
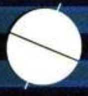


PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	April 1	April 30	April 15	April 15	April 15
Magnitude	0.2	–1.1	–3.9	1.5	–2.0
Angular Size	7.2"	5.2"	10.1"	3.9"	33.2"
Illumination	56%	93%	97%	98%	100%
Distance (AU) from Earth	0.941	1.297	1.646	2.387	5.932
Distance (AU) from Sun	0.466	0.356	0.727	1.498	4.982
Right Ascension (2000.0)	23h04.0m	1h52.5m	0h39.7m	2h56.5m	2h40.9m
Declination (2000.0)	–8°01'	10°00'	2°38'	17°02'	14°42'

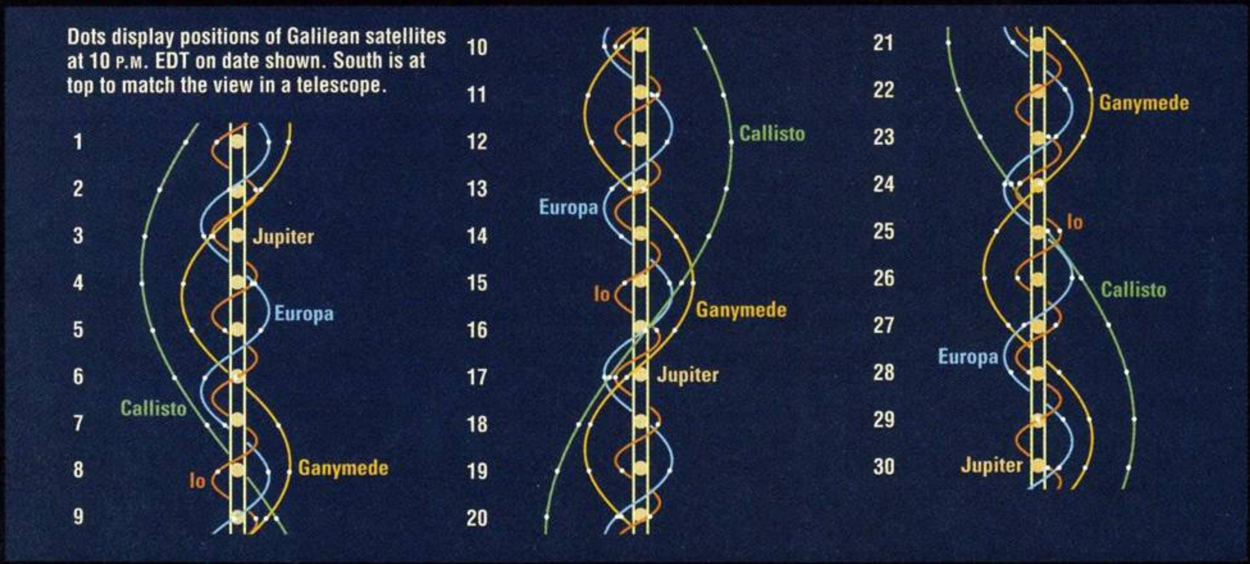


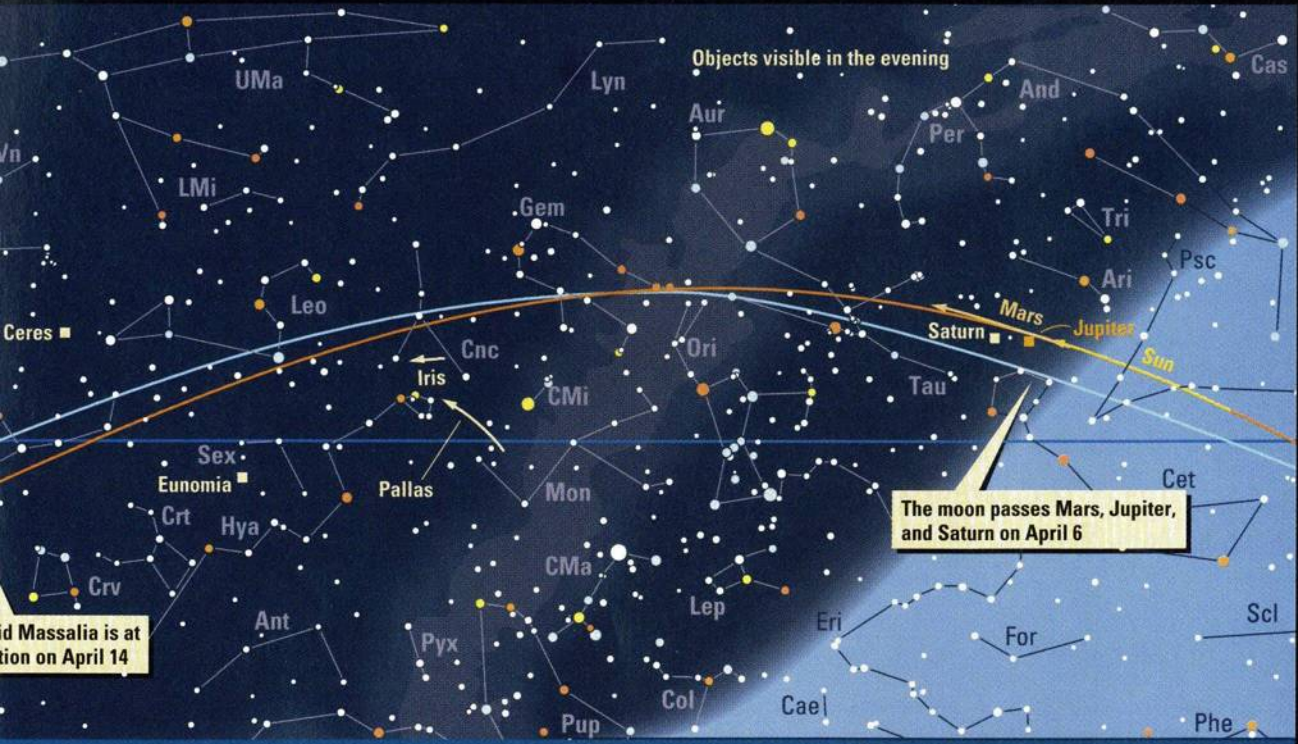




JUPITER'S MOONS

Dots display positions of Galilean satellites at 10 P.M. EDT on date shown. South is at top to match the view in a telescope.




Vn
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Ari
Leo
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Saturn
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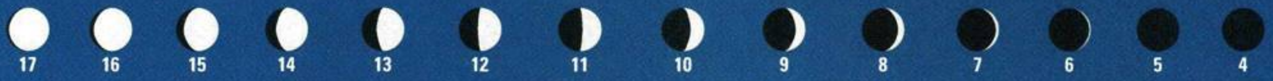
Ceres
Cnc
Iris
Ori
Tau
CMi
Sex
Eunomia
Pallas
Mon
Crt
Hya
Cet
CMa
Crv
Ant
Lep
Eri
For
Scl
Pyx
Col
Cae
Pup
Phe

Objects visible in the evening

The moon passes Mars, Jupiter, and Saturn on April 6

id Massalia is at
tion on April 14

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.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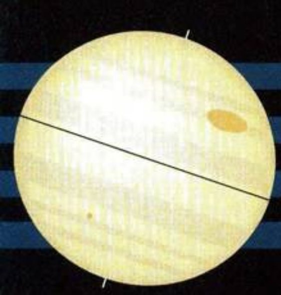
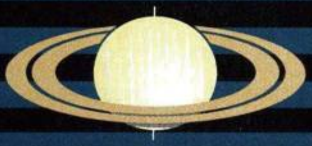
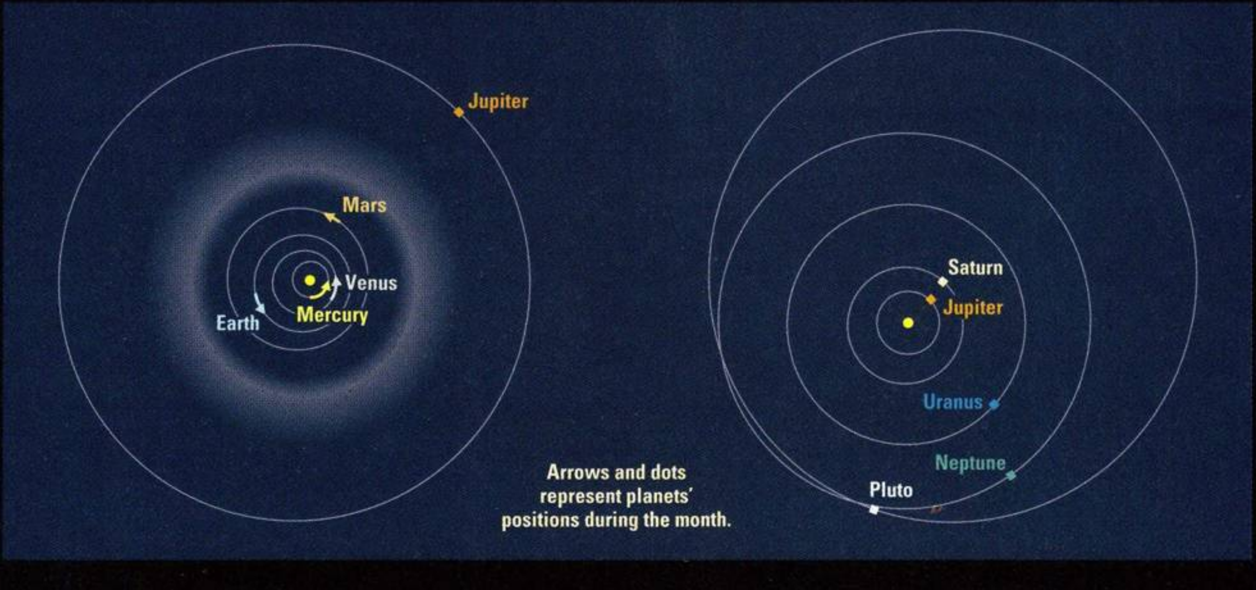




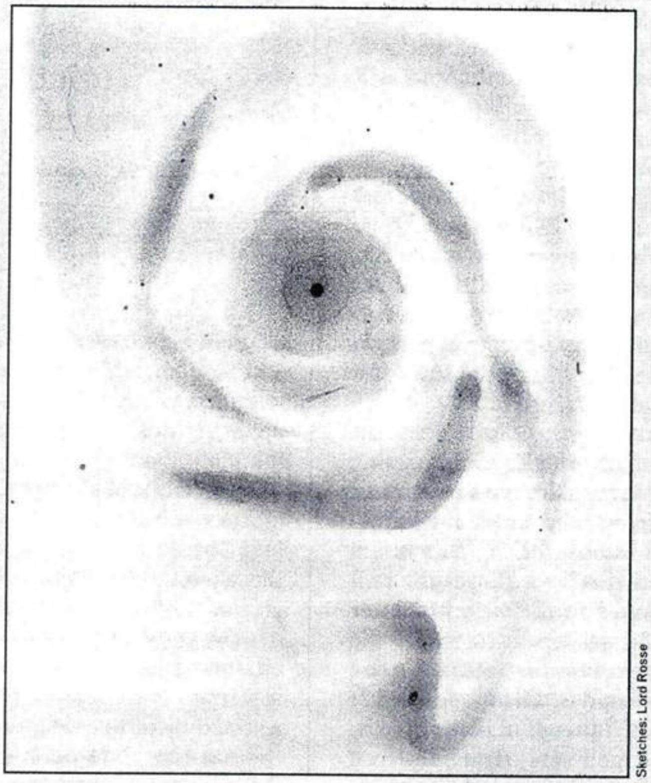
SATURN	URANUS	NEPTUNE	PLUTO
April 15	April 15	April 15	April 15
0.3	5.9	7.9	13.8
16.5"	3.5"	2.3"	0.1"
100%	100%	100%	100%
10.085	20.335	30.294	29.579
9.162	19.934	30.117	30.255
3h01.2m	21h31.2m	20h35.0m	16h50.6m
15°01'	–15°24'	–18°27'	–11°08'

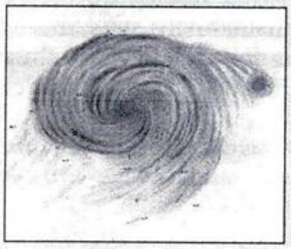
THE PLANETS IN THEIR ORBITS


Jupiter
Mars
Venus
Earth
Mercury
Saturn
Jupiter
Uranus
Neptune
Pluto

Arrows and dots represent planets' positions during the month.

FIRST VIEWS: The Whirlpool Galaxy





Sketches: Lord Rosse

M51 photo: Tony and Daphne Hallas

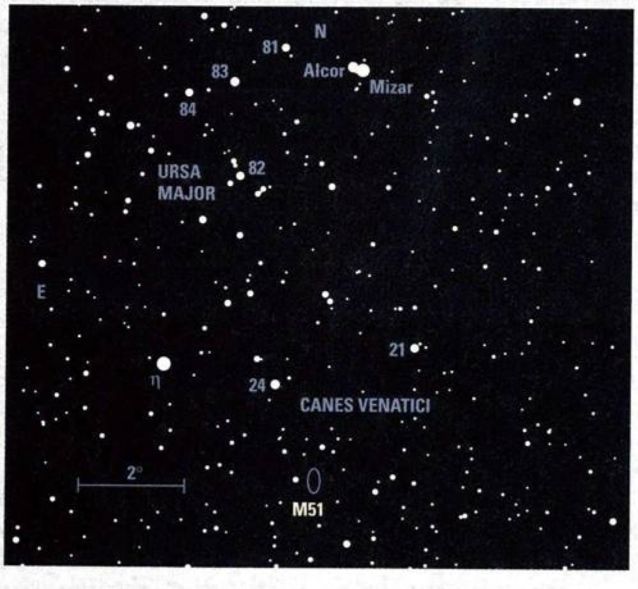
With the elegance of Archimedes's perfect spiral, the flowing form of the Whirlpool Galaxy (M51) in Canes Venatici is one of the most beautiful in the heavens. The dark lanes so perfectly separate the winding arms, it's no surprise this was the first galaxy to have been called a spiral.

To appreciate the Whirlpool, you first need to get away from the crippling light pollution of the city. Otherwise, you're left with a small, disappointing fuzz around a bright nucleus. But under the cover of darkness you can easily find it with binoculars, just off the handle of the Big Dipper, and you can even tell it's elongated.

The first human to lay eyes on the Whirlpool was the renowned French comet hunter Charles Messier, on October 13, 1773. Despite the optics of his day, the 3- to 4-inch telescopes showed Messier that the "nebula" was double. Ushering in the age of the spiral nebulae required the prowess of the 3- and 6-foot-diameter mirrors of Lord Rosse of Ireland. He used a polished copper-tin alloy called speculum and saw a spiral form years before film was sensitive enough to make the fact widely known.

Even to this day, Lord Rosse is unfairly judged about his "imaginative" and "whimsical" drawing of the Whirlpool. If you compare it to the detailed and precise drawing he and his assistants produced later, you'll see that the first simply captures the character of the spiral. Over the years, Rosse tried with his 72-inch "leviathan" telescope to measure the orbital motion of the field stars around the nucleus. Little did he suspect that M51 was millions of light-years in the background.

With a 12-inch scope, you can track down every star in Rosse's drawing, some of which are actually knots in the spiral arms. These HII regions are similar to the Milky Way's Orion Nebula. Note how the "connecting" bridge fades out in the drawing. The bridge is truly one of the toughest details to view in the Whirlpool, and many observers trick themselves into believing they see it, having the picture of the bridge captured in memory.



All illustrations: *Astronomy*/ Elisabeth Rowan

An 8-inch telescope will reveal some of M51's structure. Yes, it requires patience, magnification, and dark adaptation. Lord Rosse complained that every time he used a feeble lamp to sketch a delicate feature, it took minutes before his eyes regained sensitivity. A dark cloth over your head will help.

Roger Clark, in his book *Visual Astronomy of the Deep Sky*, recommends a wide range of magnification, maxing out past 300x even for an 8-inch scope. This is the only way to see fine structure in the bright sections of a deep-sky object, even though the fainter veils will disappear.

Center the object in the field of view and then glance to the side. This "averted vision" technique uses the sensitive rods in your eyes to detect faint light. Savor the view; take more than 30 minutes to absorb the wealth of detail in the Whirlpool.

Watch them early on in the month because they quickly become harder to see as the two giant planets move into conjunction with the sun early next month. Mars will hang on for another two months because it orbits the sun faster than the two giant planets and hence almost keeps pace with Earth, but, as always, Earth, on the inside of the orbital racetrack, creeps far enough ahead for Mars to appear on the far side of the sun from our perspective.

The three planets soon abandon the evening sky, leaving the winter stars to hang alone above the southwestern horizon two hours after sunset. Taurus the Bull sinks in the west just after the planets, escorted by the lovely star cluster, the Pleiades. Orion, southeast of Taurus, makes its exit. Rigel sets first, leaving Orion's fine belt of three equally bright stars lingering for a while until they succumb to Earth's rotation, to be followed soon after by Betelgeuse. In the ensuing two hours as we approach midnight, Gemini begins to sink also, with the feet of the Twins dropping below the horizon first.

While Taurus and Gemini are still up, a casual glance shows that the ecliptic runs right through these constellations; the line rises steeply from the horizon. The ecliptic in this position improves the possibility of viewing the reflected glow of sunlight off billions of particles of dust that lie in the plane of our solar system left by eons of cometary passes. Called the zodiacal light, this glow is somewhat fainter than the Milky Way, but from observing sites far from city lights, and especially from altitudes above a thousand feet, the cone of light along the ecliptic is unforgettable. Moonless nights during March and April are the best times in the evening to view its ethereal glow, but there are always other opportunities if clouds or light pollution hamper your chances this spring. If you live in an area that is surrounded by manmade skyglow, don't forget to look for the zodiacal light when you are on vacation, camping, or visiting friends and family in a rural location.

The full moon on April 18 is the first full moon after the spring equinox, so it determines the date of Easter, which occurs on the following Sunday, April 23. Since the previous full moon occurred only hours before the spring equinox, this "moveable feast" of Easter falls on one of the latest possible dates, which can range from March 22 to April 25. On the 18th you'll find the full moon rising right after sunset, lying among the stars of Virgo, not far from Spica. The first quarter moon occurs on April 11, and last quarter moon lands on April 26. The growing crescent moon crosses the Hyades star cluster in Taurus the Bull on April 8, but the event is only visible from the Japanese and Australasian side of the globe. Observers in that part of the world will witness a number of enchanting occultations of stars in the Hyades by the moon.

A bright gibbous moon interferes with this year's April Lyrid meteor display, which runs from April 21 to April 23 (which also marks the Christian holidays of Good Friday to Easter), but the following new moon will later benefit next month's Eta Aquarid shower.

Planetary Spring Spectacle Subsides

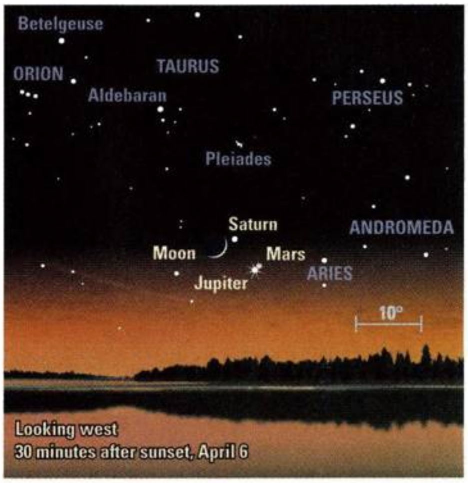
The fantastic evening sky show draws to a close by mid-month, so you'd better get out there and enjoy the view. Loads of bright objects can be seen and photographed. The best night this year to do a big public relations astronomy event is April 6. The beautiful crescent moon will join Mars, Jupiter, and Saturn in a dramatic, tight grouping, about 45 minutes after sunset.

Keep an eye out for Mars. It's the diminutive pale-orange starlike object just to Jupiter's lower right. In the first five days of April, Mars will climb to the upper right of Jupiter. Binoculars will be the instrument to use for this marvelous conjunction. Mars continues its rapid motion and passes Saturn on the 14th, just before the twilight glow swallows the planetary trio. When is the last time you can find them with binoculars?

Any type of camera is suitable for capturing great shots of the solar system in action. You can even get away without a tripod by sitting your camera on top of the car roof. The point here is that it's definitely worth trying, and you'll be pleasantly surprised by the pretty pictures. Tape over the flash bulb on an instamatic camera so that it won't illuminate foreground objects.

For 35mm cameras, use 100 ISO film. Faster film such as 400 will produce grainy enlarged prints. At f/1.4, your exposures will typically be about $\frac{1}{8}$ to $\frac{1}{15}$ of a second. Automatic cameras will try and compensate for the lower light levels by exposing too much. If your camera lets you, override its recommendation by underexposing one or two settings.

Be artistic; seek out unique foregrounds for your pictures such as architecturally interesting old buildings, natural scenery unique to your area, or even people participating in various activities. A roll of film is pretty cheap compared to your annual astronomy budget, so don't be afraid to shoot a lot, and bracket your exposures, especially on the shorter side of what your light meter recommends.



Looking west
30 minutes after sunset, April 6

Following the constellations along the ecliptic, after Gemini, we come to Cancer the Crab, a faint grouping that houses M44, the Beehive star cluster. In Latin the cluster is called Praesepe, which means "the manger." The fine galactic cluster contains about 40 stars visible in binoculars.

Next to Cancer and farther along the ecliptic to the east lies Leo the Lion. Regulus is its brightest star, which lies high in the south at 10 P.M. local daylight saving time. Above Regulus floats an easy pattern of stars to find, the inverted question mark — a line of stars that marks the "sickle" asterism. Five degrees to the west of Leo is a star well-known as a Mira-type variable star, R Leonis, an easy binocular object that reaches its peak in late April. Is it visible to the naked eye? (See "Familiar Friends," page 67.)

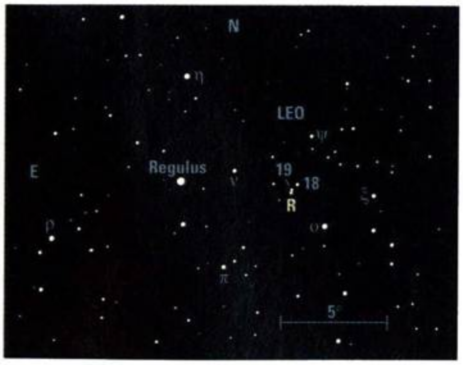
The constellation Virgo rises in the east during the evening, and its brightest star, Spica, when joined by an imaginary line to Regulus, delineates the ecliptic well. The "Y"-shaped bowl of stars, a familiar group making up part of the second largest constellation in the sky, lies to the northwest of Spica. North of Virgo's bowl, the faint constellation Coma Berenices houses the North Galactic Pole — the location of the point where an imaginary line extending from the rotation axis of our Galaxy intersects the celestial sphere. This explains the lack of bright stars — we are looking right out of our Galaxy perpendicular to the disk toward deep, intergalactic space. This entire region of sky is dotted with faint smudges of light, star cities, and galaxies. Within Coma

Familiar Friends

Observers who have become friends with the sky gain a deep satisfaction through their sense of familiarity with the stars. A quick glance around can be like reading a neighborhood newsletter, reporting tidbits such as "The famous variable star Mira has brightened to naked-eye visibility again." This spring, get to know another variable star, R Leonis in Leo the Lion. Once you get familiar with it, you can check up on it, at any time, without a chart.

R Leonis is, as noted variable-star observer David Levy says, "a stately star," taking some 313 days to cycle from a bright magnitude 5.8 down to 10, then back again. Sometimes we get a delightful surprise and it climbs above 5th magnitude. Expect it to peak this year at the end of April.

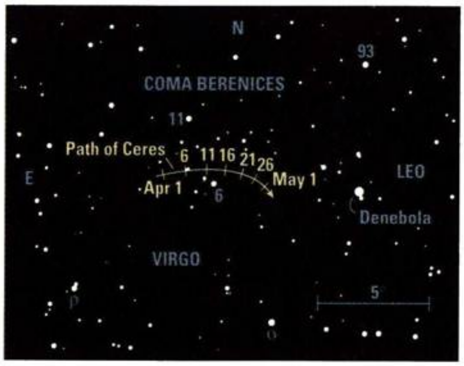
Use binoculars to follow it every couple weeks through early summer. It's a snap to find, being only one binocular field to the right (west), of Regulus, the heart of Leo. You should see a hockey-stick shape, with R Leonis at the tip of the blade, which is pointing south. The corner and handle of the stick are 6.5- and 5.6-magnitude stars. See if you can note a change in color as R Leonis slowly begins to fade.



If you have access to a prism or grating eyepiece, you must check it out. The rainbow spectrum of R Leonis not only has much less blue in it than other stars, but it's got a number of really obvious black absorption lines cutting it into pieces. For an amateur, it doesn't really matter if you don't know what it means, it's just fascinating to see. The AAVSO, the American Association of Variable Star Observers, can help you learn more at www.aavso.org.

An Asteroid for Binoculars

On any night this month head into the backyard with a pair of binoculars to claim the number one asteroid. Ceres was the first minor planet to be detected, on January 1, 1801, by the Italian astronomer and monk Giuseppe Piazzi. At magnitude 7.0, the 570-mile-wide (910-km) crater-pocked ball appears brighter than most stars in its immediate vicinity. Even with the moon in the sky, Ceres will punch through the added light.



Start with the large, right-angled triangle that makes up Leo's hindquarters, then slide directly east, perhaps a bit more than one binocular field of view (6.5°), to find the star 6 Comae Berenices glowing at magnitude 5.5. Ceres lies no farther than 2.5° from 6 Comae for the whole month.

Except for two 6.5-magnitude stars heading to the east-northeast in a straight line from 6 Comae, everything else in the field will be fainter than Ceres. Make a sketch of the field and then come back again in two nights to see the moderately obvious motion of that little "star" Ceres.

Two other asteroids have been found to have satellites. Does Ceres? Astronomers don't know, but the odds seem fairly high.

OBSERVER'S CHALLENGE: Mercury Makes a Pass at Venus

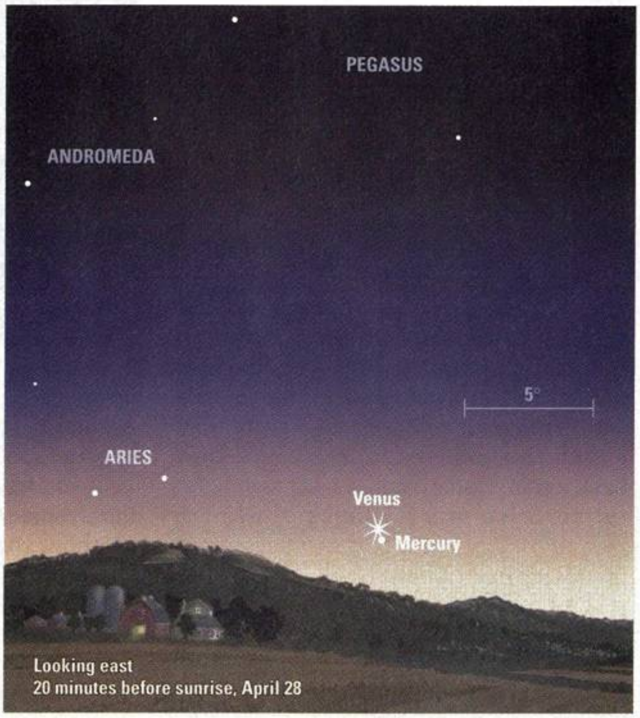
Every couple of years, a pair of planets lines up very closely. Last year we had the stunning Venus-Jupiter conjunction, and late this month we can watch Venus and Mercury perform a daylight bypass dance. At their closest, on the 28th, the two will be 20' apart (equal to ⅔ of the moon's width).

What makes this event worth the effort will be the chance to compare the two inner planets side by side for size and phase. Venus is actually on the far side of the sun, so it's small (10") and just short of being perfectly round. Similarly, Mercury, at magnitude –1, will shine with a 91-percent-lit phase but appear half as big. In reality, Venus is 2.5 times larger than Mercury but loses some apparent size because it is farther away.

The easiest way to find Venus during the day is to use an equatorial scope and offset from the sun. Warning: Cover the front of your scope and finder while you fix on the sun by making the scope's shadow as small as possible, or use a solar filter. After you offset, leave the cap on the finder for added safety.

Use the setting circles to move south 5° and 14', then shift west (right) 43 minutes of R.A. Mercury lies 18' southeast, slightly more than half the moon's width. On the 27th, Mercury is 45' southwest of Venus, and on the 29th it lies 50' east.

Those without setting circles or computerized accessories can still find Venus the sly way. Set up your telescope in morning twilight just before 5 A.M., point it at the bright star Altair, then cover the front and finder. Return to your scope 5 hours and 50 minutes later, and Venus should be right there. On the 29th, Venus and Mercury will have shifted almost 1° farther north, keeping up with the sun's apparent northward motion. You'll first have to find Altair and then shift your telescope up 1°, or two moon widths.



Looking east
20 minutes before sunrise, April 28

Berenices lurks a more local member of the heavens, the asteroid Ceres. Ceres is a few weeks past opposition and an easy binocular object at magnitude 7.0. It lies close to 6 Comae Berenices on April 12. (See "An Asteroid for Binoculars," page 67.)

The brighter members of the Virgo supercluster of galaxies can be found with most amateur telescopes, though a 6-inch scope is ideal. Begin with M59 and M60, two elliptical galaxies that lie 1.25° north of the magnitude 4.9 star Rho (ρ) Virginis. Discovered by J. G. Kohler while observing a comet in 1779, Charles Messier himself recorded the objects a few days later, and they became two of his designated catalog entries. The pair is visible together in a low-power eyepiece as two small, dim smudges of light. Notice that close to M60 is another dim galaxy, two magnitudes fainter than the magnitude 9.0 elliptical galaxies. Appearing as a fuzzy "star" in 4-inch telescopes, larger scopes will reveal more features of the spiral galaxy NGC 4647 (NGC = *New General Catalogue*, the listing compiled by John L. E. Dreyer).

Careful scanning of this region, greatly aided by a good star atlas, will reveal eight more Messier objects, along with dozens of NGC galaxies. Choose a night of little moonlight and gaze outward to these star cities millions of light-years away, each one home to many billions of stars.

High overhead, the Big Dipper swings through its upper culmination. It also contains a number of galaxies, though the most famous galaxy, M51, actually lies in the neighboring constellation of Canes Venatici. (See "FIRST VIEWS: The Whirlpool Galaxy," page 65.) Called the Whirlpool Galaxy, M51 lies 3.5° southwest of Eta (η) Ursae Majoris, also known as Alkaid, the star that marks the end of the handle of the Big Dipper. Small telescopes will show a distinctive double patch of light. Scopes larger than 8 inches will begin to reveal the spiral arms.

During the first two hours after midnight, the summer triangle rises above the eastern horizon, led by the brilliant magnitude 0 star Vega in the constellation Lyra the Harp. Its reappearance also allows for an early look at the beautiful Ring Nebula (M57), lying midway between Beta (β) and Gamma (γ) Lyrae. This exquisite and delicate ring appears perfect through an 8-inch scope — lovers of the night sky are always drawn to this planetary for its ability to stun with each return visit.

By 2 A.M. local time in early April, Aquila the Eagle soars above the eastern

The Straight Wall

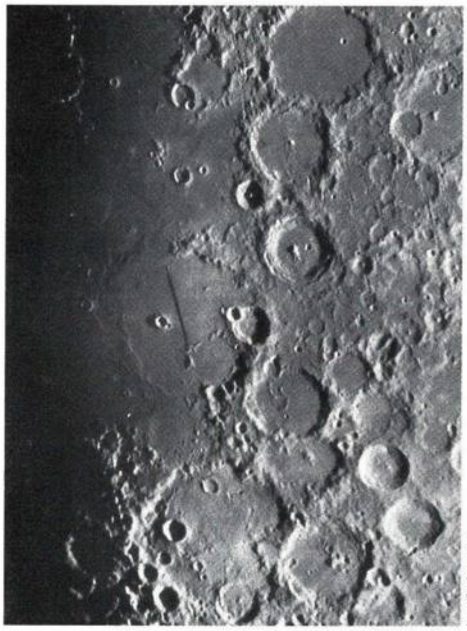
The moon is a fantastic world to visit. If you enjoy watching the terrestrial play of light and color on clouds during twilight, then there's no place like the moon. In the span of 20 minutes, you can watch the texture of the surface transform and witness the glory of sunlight spilling freshly onto a plain between jagged black shadows, a scene more dynamic than any planet can deliver. All this and the moon is visible in the smallest telescopes, or just binoculars.

One of the most popular features on the moon is the "Straight Wall," whose proper name is Rupes Recta. It stands out next to snakelike rilles and a myriad of round craters. When the light is right, a few hours after sunrise falls upon it, the scarp casts a long black shadow almost down the middle of a large circular feature. Within a few days, the Straight Wall has vanished because the angle of the sun hitting it has changed, causing the shadow to disappear.

Rupes Recta runs about 70 miles (110 km) long. Its slope is not sharp. A modest grade of 7° gives it one step down for every nine across. Before detailed measurements, observers thought it was a cliff. When the sun shines on the face of the slope (which occurs near a last quarter moon), the Straight Wall becomes visible as a line brighter than its surroundings. A half-submerged crater rim on the south end completes the imaginative picture of a swashbuckling sword.

The Straight Wall becomes visible on the evening of April 12. Its black shadow is already retreating, so make an effort to note its position and check again in an hour. It will be disappearing in all but the largest scopes by the 14th. The Wall will reappear as a white line on the morning of the 24th, and its sunset occurs on the 26th. The last quarter moon is best observed about an hour before sunrise. Hope for a cloudless sky.

While you're at it, check out the size of the moon. On the 12th, the moon will have passed its closest point to Earth (perigee). By April 24, the moon will be at its farthest (apogee), and so it will appear to be smaller. If you use an eyepiece that just catches the whole moon in the field, you can easily see the difference in apparent sizes.



Lee C. Coombs

horizon. Its principle star, Altair, shining at magnitude 0.8, completes the summer triangle. Altair resides 16.8 light-years from Earth, making it one of the sun's closest neighbors. This nearby star was used by Apollo astronauts to help guide their spacecraft. Aquila was the focus of attention last winter when Nova Aquilae 1999 erupted and burst onto the scene reaching magnitude 4.0. It quickly faded and is now beyond view of binoculars. Many remember their first view of the nova while standing out in the cold winter nights of early December. Now that four months have passed, the weather is warming and Aquila returns to us in the morning sky, triggering memories of those nights searching for a new friend. One wonders what surprises Aquila will bring.

Our daytime star is expected to be at peak activity this year. It's almost guaranteed that you will find numerous sunspots on the sun on any day this year. But do take care — observing the sun should never be done casually. The sun is exceedingly bright. Not only can its heat damage an eyepiece, but a one-second glance through any optical device will damage your retina at the back of the eye beyond repair. Pain cannot warn you: The back of the eye doesn't have nerves, so you won't feel a thing.

Safe viewing of the sun is easy — point your telescope toward the sun, ensuring no one has his or her eye near the eyepiece. Use a piece of white card, hold it about one foot away from the eyepiece, and move the telescope around until you see an image of the sun projected onto the card. Now focus the image, and sunspots will snap into view.

Daily monitoring of sunspot positions will allow you to quickly calculate the rotation rate of the sun. Try this for sunspots at a variety of latitudes — you may be surprised by the result. The sun doesn't rotate as a solid object, so rotation periods vary depending on latitude. Around the limb, look for subtle, bright patches in the photosphere near sunspots. These bright features called faculae are slightly hotter than the surrounding photosphere. The sun also dims toward its own edges, known as limb darkening.

Because the sun is a gaseous ball and has no solid surface like a planet, when we view the limb of the sun we are viewing regions higher in the atmosphere than the central part of the disk. The higher photosphere is slightly cooler, so it emits less light. Making solar observing a regular part of your routine will help you get extra mileage out of your astronomy equipment and add many productive hours to your hobby.

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

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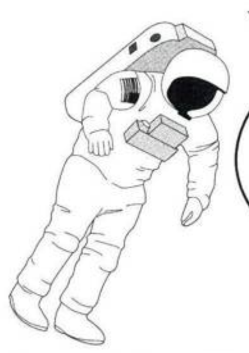

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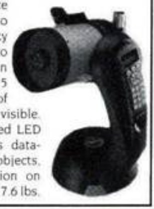

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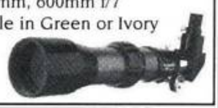

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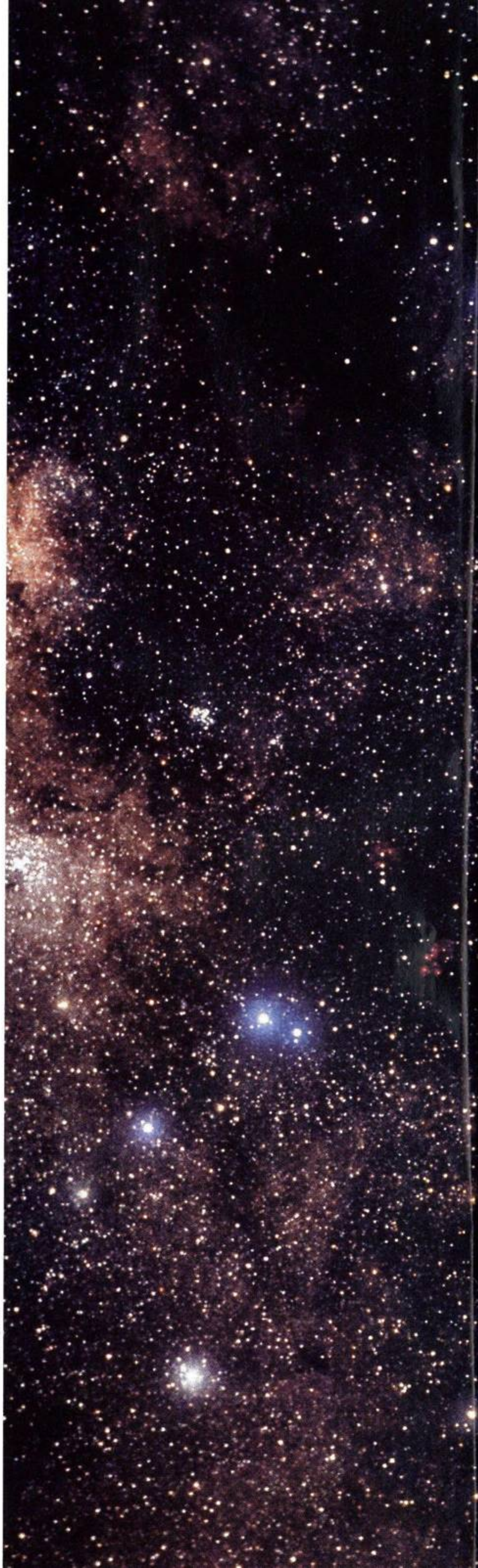
STAR STRUCK

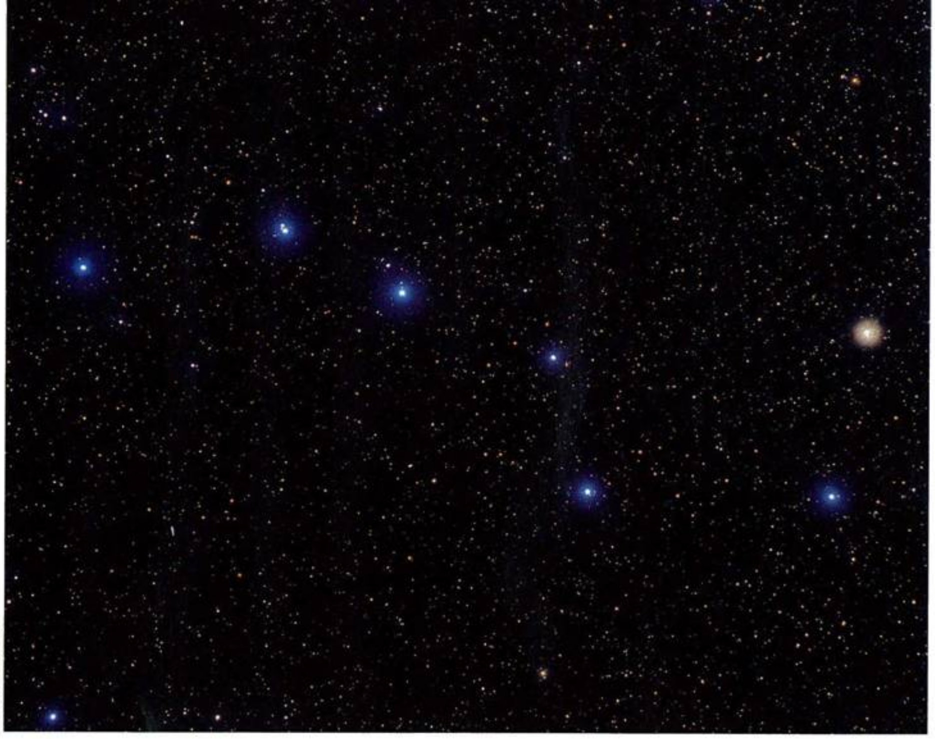
Clever astrophotographers are revamping the way we look at constellations.

Photographs by Bill and Sally Fletcher

In the old days, no one shot constellations. That's because the results looked like grains of salt spilled across black construction paper. Big deal. But now the ingenuity of backyard astrophotographers is transforming constellation shots into alluring portraits of bright stars that glow amidst colorful halos. The trick is to shoot under a dark sky and employ a relatively fast, wide-angle lens, fine-grained color film, a long exposure, and — during the exposure — screw a soft filter onto the lens. The filter, variously called a soft, fogging, or diffusing filter, is the magic bullet that gently blurs the stream of photons from the brightest stars (those of 2nd magnitude or brighter) into a soft halo and accentuates the stars' colors far more than an ordinary shot would.



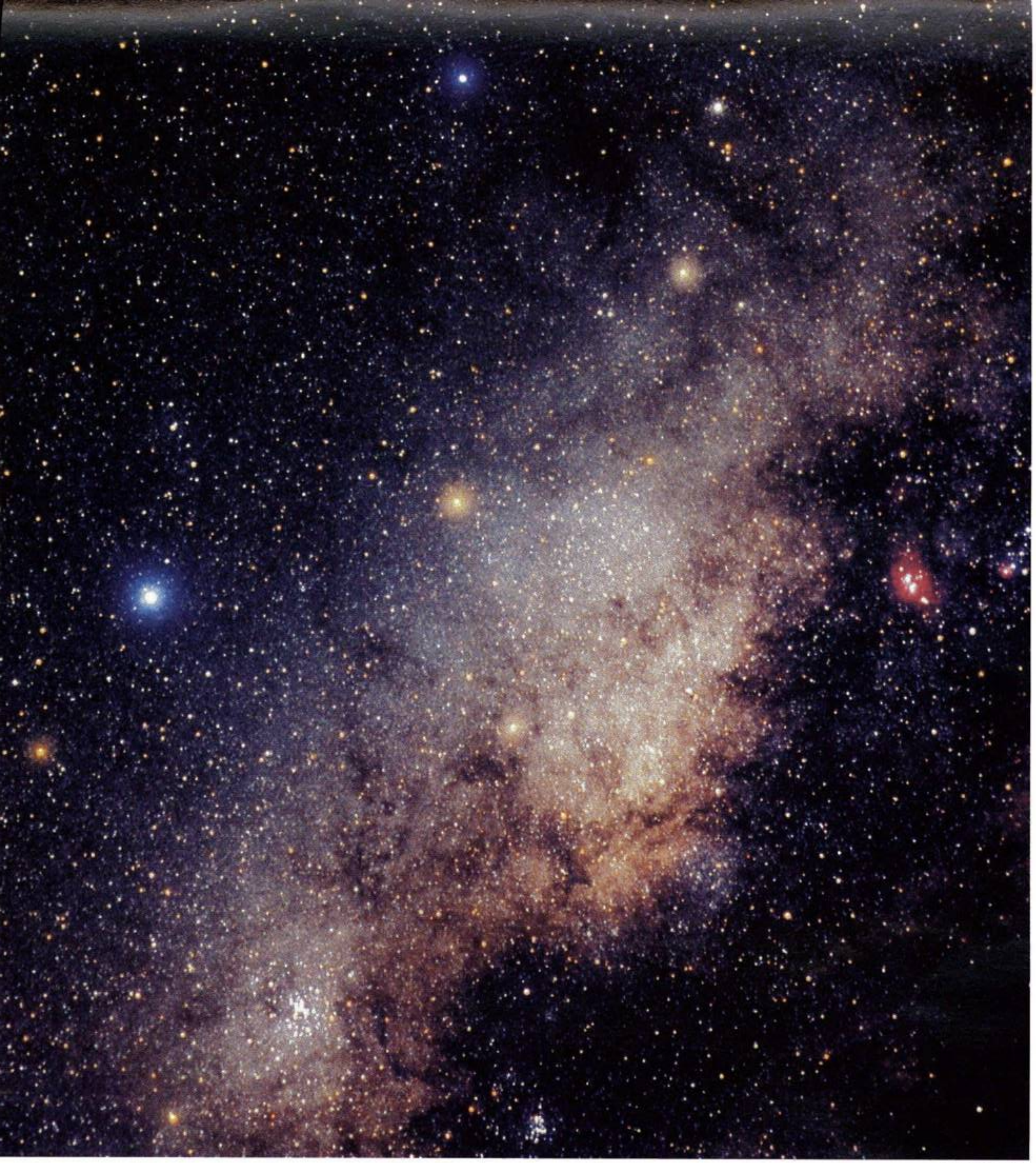
Scorpius



Ursa Major

"Light from the bright stars slowly scatters on the film, revealing the stars' natural colors," says California astrophotographer Bill Fletcher, one of the pioneers of this dramatic technique. Along with his wife, Sally, Fletcher has produced a stunning portfolio of constellation images using a 90mm lens at f/5.6, a medium-format Pentax 6x7 cm camera, Kodak Pro PPF 400 film, and the soft filter. "We expose for a total of 60 minutes and use the filter for 12 to 20 minutes during that time, depending on how much 'fogging' we want," he says. "We do the entire process twice and then sandwich the two exposures to reduce film grain and boost contrast."

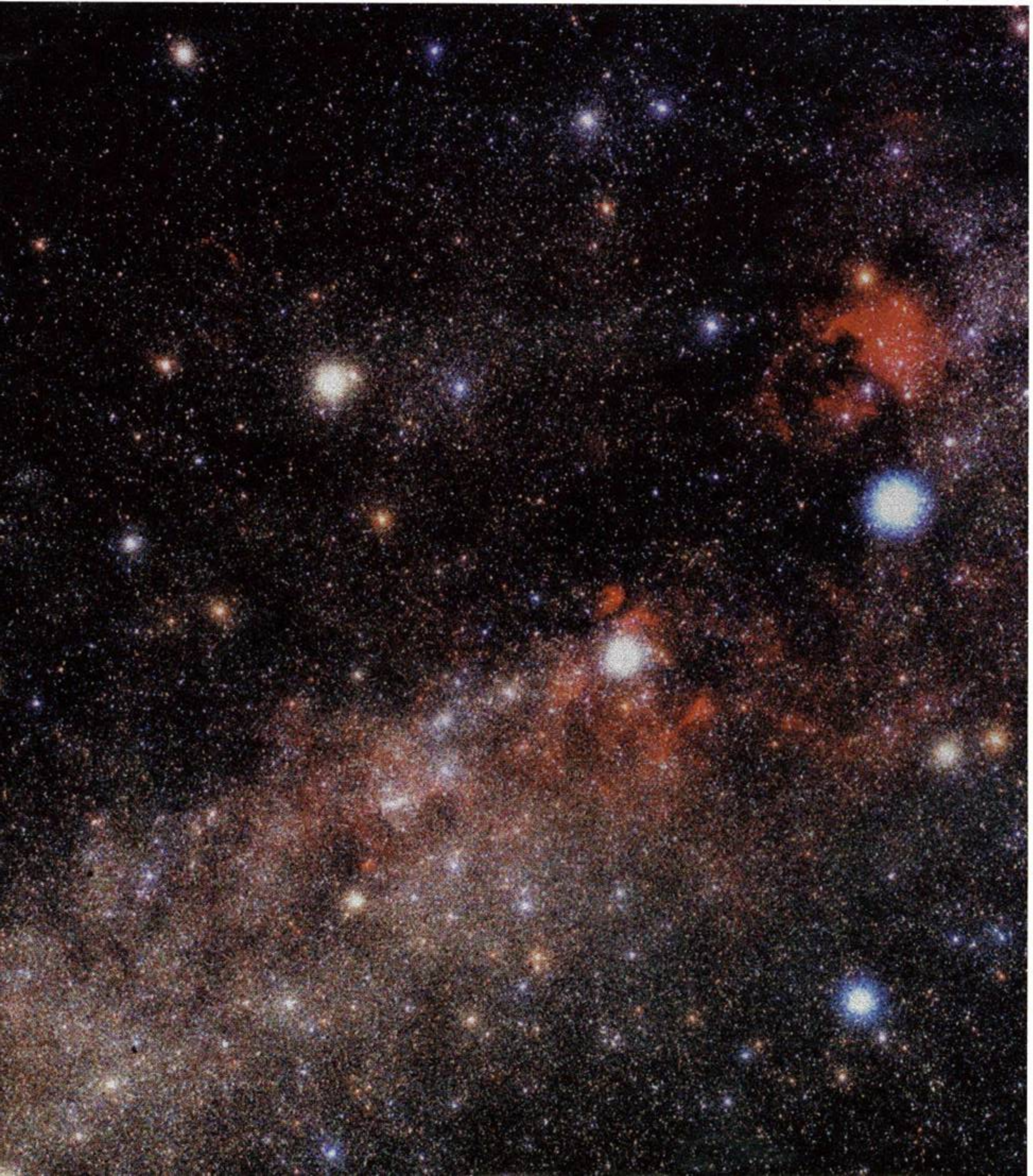
The result portrays the treasures of the constellations magnificently. In the Fletchers' portrait of Ursa Major (above), Dubhe (Alpha Ursae Majoris), the star on the end of the Big Dipper's spout, appears yellowish — true to its nature as a K-type giant and far different from the cool blue of the other Dipper stars, all young A-type suns born in the same cluster. In the familiar W-shape of Cassiopeia (opposite page), Schedar (Alpha Cassiopeiae) likewise appears yellow and the rest of the bright stars blue. Again, it is the lone K-type star betwixt a swarm of younger stars that float atop a background of thousands of more distant Milky Way suns. In the richness of the



Sagittarius

Cassiopeia

Cygnus and Lyra (50mm lens at f/4, Kodak 200 film pushed to ISO 800, 20-minute exposure with a soft filter) Gianni Tumino



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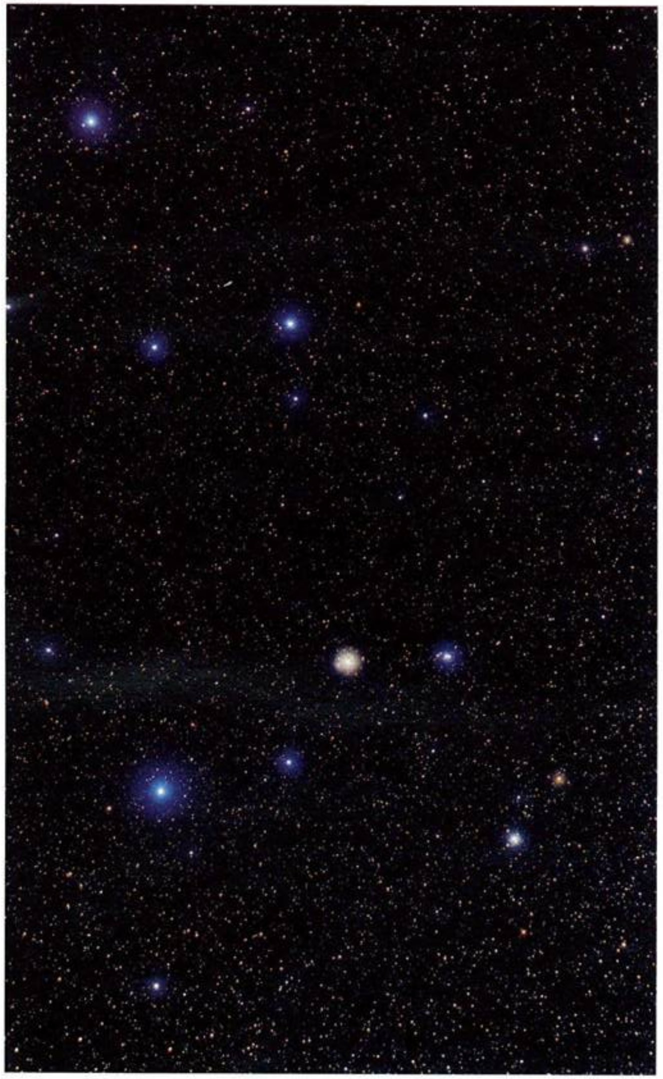


Cassiopeia Milky Way, also visible are reddish swaths of the star-forming regions IC 1805 and IC 1848 (lower left), IC 281 (smaller, near Schedar), and the result of the ruddy gas's collapse — newborn stars in the Double Cluster in Perseus (lower left).

Perhaps most spectacular are the constellations that form the spine of the summer Milky Way, illustrated in breathtaking portraits of Sagittarius, Cygnus, and Scorpius. Covered by the shotgun blast of speckles from distant white, blue, and yellow stars, the tapestry of the Sagittarius Milky Way (pages 74–75) contains dozens of deep-sky objects. Among the most recognized by amateur observers are the Lagoon and Trifid nebulae near the top of the image, the sprawling star clusters M6 and M7 at the right, and an intricate network of dark nebulae winding its way across the left side. No less spectacular are the multitude of clusters, reddish nebulae, and dark clouds in Scorpius, (page 73) and here too lies the globular star cluster M4, immediately right of the brightest star, Antares (a yellow beacon). Cygnus (below) contains the familiar blend of stars, clusters, and gas clouds in a completely different configuration, led by the gargantuan form of the North America Nebula at the top left.

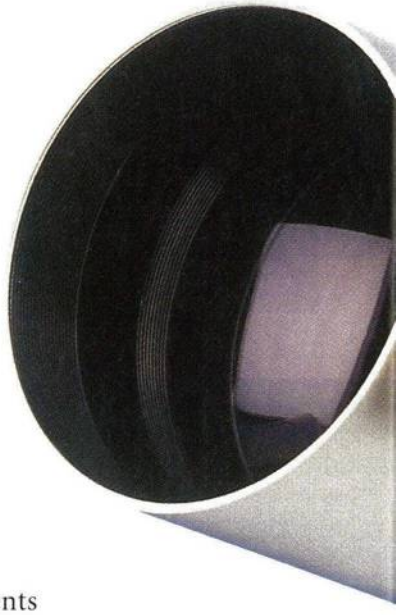
Aside from seeing the differences in star colors captured well on paper and the beauty of a host of deep-sky objects framed among the stars, these spectacular and clever constellation shots give us the ability to see into the Galaxy. The sky, after all, is not merely a two-dimensional fabric against which we see a rotating show of different objects. Diffusing the light from bright stars, capturing their colors, and securing the myriad backdrop of thousands of more distant suns accentuates our ability to perceive a three-dimensional view of space. In the future, everyone will shoot constellations. — David J. Eicher

Canis Major

Paired Vixens

Two 4.9-inch f/5 refractors power the Orion-Vixen giant zoom binoculars.

By Phil Harrington



Mention binoculars and small, low-power, hand-held instruments come to mind. While the majority of these are just that, a special breed of large binoculars far exceeds this stereotype. Giant binoculars usually have objective lenses larger than 70mm with magnifications of 10x or greater. All are too heavy to support by hand and must be used with a tripod or other mount.

Recently, Orion Telescope Center of Santa Cruz, California, introduced three mammoth binoculars into the United States. The trio is manufactured by Vixen Optical Industries of Tokorozawa, Japan — a company long known for excellent telescopes and eyepieces. This report examines the newest member of that group, an impressive pair of 25x to 75x zoom binoculars. No ordinary giant binoculars, these heavyweights are, in effect, a pair of 4.9-inch f/5 achromatic refractors mounted in tandem and outfitted with a pair of Vixen Lanthanum 8mm to 25mm zoom eyepieces, a formidable combination for probing the night sky. The eyepieces are continuously variable but have preset detents at 25, 38, 50, and 75 power.

All Photos *Astronomy*: William Zuback

ORION

The entire outfit (binoculars, tripod, and alt-azimuth mount) is shipped directly from the factory. The binoculars are painted a glossy, baked-enamel white, and the fork mount is painted black. I was immediately impressed by the setup's light weight. The aluminum tripod and mounting are quite light for such heavy binoculars. The glasses themselves tilt the scales at 24 pounds, but the complete package only weighs 38 pounds.

The Nuts and Bolts

Assembling the binoculars is a five-minute operation. The fork-style alt-azimuth mount easily connects to the tripod and is secured by a large, captive bolt. Although they may be on the heavy side for some people, a large handle set between the barrels makes transporting them easier.

Once placed in the fork mount, two hinged clamps hold the binoculars in place — one on each arm. The clamps also serve as an altitude brake to keep the binoculars from moving accidentally during use. This simple, effective arrangement reflects Vixen's thoughtful design. It would have been less expensive to use a nut and bolt method of attaching the binoculars, but that would require the use of hand tools and loose hardware. Ever fumble around at night for a bolt that accidentally fell into high grass? It's not a pleasant way to begin an observing session.

The fork arms may be tilted or positioned vertically. Tilting the mount offsets the binoculars from the center of the tripod. This makes it much easier to look through the eyepieces when the glasses themselves are tilted at angles greater than 45°. Although this shifts the center of gravity away from the center of the tripod, it does not affect the mount's stability.

Tilting the arms is the only part of setup that requires a separate tool, a small Allen wrench, which is supplied. In practice, I left the arms tilted at 45°, so readjustment was unnecessary, but had I wanted to adjust them again in the field, I would have had to remember to bring the wrench with me. It would be nice if Vixen had added a small retention mount on the inside of one of the fork arms for the Allen wrench, but this is a small point of contention.

Two Vixen Lanthanum 8mm to 25mm zoom eyepieces take your view from 25x to 75x. To adjust for individual eye separation, pivot the two round prism assemblies until the images merge.

38X
50X
75X
38X
50X
75X

At first, I expected the fork mounting to be too lightweight to support the binoculars, but a quick test showed that it was up to the task. With the tripod legs fully extended and the binoculars zoomed to 75x, I rapped the side of the instrument barrel sharply with the ball of my hand. My own subjective rule is that if an instrument stops vibrating after no more than three seconds, stability is "excellent," from 4 to 6 seconds, stability is "good"; 7 to 10 seconds rates "acceptable"; while greater than 10 seconds is "unacceptable." The Vixen binoculars averaged between 4 and 5 seconds.

Despite some creaking when the binoculars were moved to the left or right, the alt-azimuth mount moved very smoothly. Panning back and forth, up and down was a pleasure, especially along the Milky Way. Despite their size, these binoculars still conveyed that sense of freedom not often experienced through a telescope.

As with all binoculars, it is important to adjust them to the individual observer. The Vixen's interocular distance (the spacing between the two eyepieces) is adjusted to match the observer by pivoting the round prism assemblies until the two fields of view merge. As with all monster binoculars, focusing is done individually by turning the barrel of each eyepiece. Although this routine may seem inconvenient to some, focusing is smooth and simple to achieve. Twisting the second ring on each barrel also individually sets the magnification for each eyepiece.

A Binocular View

Once everything was set, I began my tour of the universe. Even before aiming at a particular target, I was immediately impressed by how sharp star images were across the entire field of view, regardless of magnification. Coma and curvature of the field, two common binocular aberrations, especially in zoom models, were absent. Eyeglass wearers will also appreciate the 20mm eye relief. Even those who wear glasses because of astigmatism should have little trouble seeing the full field of view.

To work properly, binocular barrels must be perfectly aligned parallel to one another. If the barrels are misaligned, even by a small amount, the images can cause eye fatigue and headaches. The problem is tough enough to avoid in smaller models, but it is especially important at these high magnifications. Because of their girth, I feared the Vixen binoculars might flex and shift when moved from horizon to zenith. But after repeated use, they remained perfectly aligned and unvarying, regardless of angle or viewing position.

I enjoyed some spectacular deep-sky sights through these binoculars. Wide-field views of the Orion Nebula (M42), the Pleiades (M45), Double Cluster (NGC 869 and NGC 884), and Andromeda Galaxy (M31) were especially memorable. One of the most impressive sights for me was that of the Andromeda Galaxy at 25x. To one side stood the small companion galaxy M32, to the other the ghostly glow of a second companion (NGC 205), while the silhouette of one of M31's dark rifts girded the galactic disk. Other sights, such as resolving stars in globular clusters M13 and M22, looking at the billowing nebulous patches of the Lagoon Nebula (M8), or spotting the dim glow of the Veil Nebula (NGC 6960 and NGC 6992–5) also proved that two eyes are indeed better than one.

Pluses and Minuses

As much as I enjoyed the views, all is not perfect with these binoculars. Earlier, I noted that each eyepiece's focusing mechanism was smooth and simple. That's a good thing, since the eyepieces are not parfocal across their zoom range. In other words, they had to be refocused whenever the eyepieces were zoomed in or out, a real inconvenience. I also caught myself confusing the focusing rings on the eyepieces with those that vary the zoom. Granted, it's just a matter of becoming familiar with what each ring does, but the constant need to refocus was disappointing.

Although coma and curvature of field were nowhere to be found, false color or secondary spectrum plagued the view of bright objects. Celestial sights such as Jupiter and its moons, the moon, and Saturn's beautiful rings were all sharp. Unfortunately, they were also marred by unnatural, purplish edges. These binoculars use fast, f/5 achromatic objectives. They cannot and do not eliminate secondary spectrum as completely as instruments with apochromatic objectives or slower focal ratios. So, while the false color was not surprising, I found the purplish rim annoying.

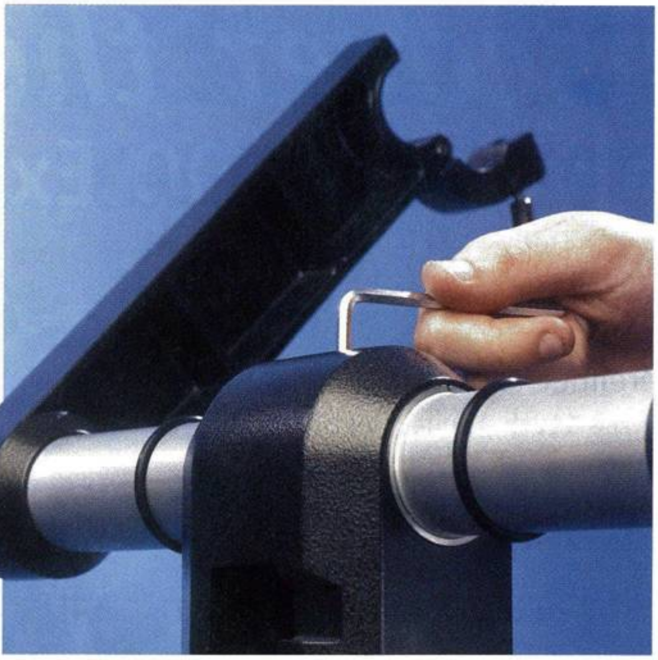
I was also disappointed that the zoom eyepieces were not removable. Vixen zoom eyepieces are among the finest sold today, but I would have preferred the ability to substitute my own premium eyepieces in their place. Not only would removable eyepieces greatly expand the magnification range, they would also let observers mate the binoculars with a pair of nebula filters. Together, that would have been a dynamite setup for viewing large emission nebulae. It's unfortunate that option isn't available.

Although the binoculars do not come with a finderscope, a dovetail base is supplied that will accept a number of Vixen-manufactured finders — a must-have accessory in my opinion. An optional 7x50 finder is available through Orion for $200. Although, for the cost of these binoculars, I am disappointed that Vixen doesn't supply a standard, small 6x finder. Should you prefer to leave the driving to someone else, the fork mount may also be outfitted with custom-fit digital setting circles.

Another must with these binoculars is an adjustable observing chair. The eyepieces, tilted at 45°, can be difficult to get to when the binoculars are looking at an object much above 60° in altitude. A chair will make viewing such objects more comfortable. As with refracting telescopes, 45° prisms are better suited for terrestrial viewing. A 90°-prism setup would be more conducive to astronomical observing.

A double-eyed view of the universe comes at a price. For the same investment, an observer can purchase a 5-inch apochromatic refractor (without a mount), a 10-inch computer-guided Schmidt-Cassegrain telescope, or a premium 18-inch Newtonian reflector and still have money left for a few eyepieces or accessories. Of course, as good as those instruments are, they only show a single-eyed view of the universe.

Binocular enthusiasts may also select among other gargantuan binoculars by Nikon, Fujinon, and Miyauchi. Miyauchi's line of 100mm binoculars is especially noteworthy, since they offer both semi-apochromatic and apochromatic models, which have superior false-color, as well as interchangeable eyepieces. None of these other binoculars, however, comes with its own mounting, yet all still carry exorbitant price tags ranging from $2,300 to more than $13,000. When you take that into consideration, the Vixen 25–75x125 binoculars are hard to beat in both price and performance.



Use an Allen wrench to set the fork-mount at a 45° angle. Two hinged clamps, one on each tine of the "fork," hold the binoculars in place.

Vixen 125 Zoom Binoculars

Objective lens: 125mm (4.9 inches)
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Phil Harrington is a frequent contributor to Astronomy *and the author of five books. Visit his home page at http://ourworld.compuserve.com/homepages/pharrington.*

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In Cyber Color

With a monochromatic CCD camera and a little ingenuity, you can capture the colors of the sky.

by Gregory Terrance

You've spent the night taking digital astroimages, tirelessly finding, focusing, and saving the results. After careful processing the next morning, you proudly show your final images to friends and family, only to be confounded with the inevitable question about why they aren't in color. Dolefully, you mumble an explanation that the CCDs used for celestial astroimaging are monochromatic, or "black-and-white," and cannot produce color images. Although everyone seems satisfied with your response, you secretly walk away determined to capture color CCD images in the future. And there is a way. Read on.

The Orion Nebula (M42) imaged with a 16-inch SCT at f/6.3, Pictor 1616 XTE CCD camera, and exposures of 8 seconds (red), 20 seconds (blue), and 30 seconds (green). Jack Newton

Years ago, photographic films were limited to black-and-white images. Today, the film used for color photography is not a single layer of film, but rather three (or more) filtered layers of black-and-white emulsion stacked together. When you take a color photograph, you're in essence capturing a bunch of monochromatic images at once. The film holds these images in register with each other so that after printing, a color image emerges.

Astronomers attack the problem by stacking CCD images electronically. To create a tricolor image, an object has to be imaged through red, green, and blue (RGB) filters and then composited using computer software. Tricolor CCD imaging requires the same basic equipment needed for monochromatic imaging; in addition to your CCD camera, computer, and telescope, you'll need a set of filters, a method of interchanging them, and some extra software.

Filters allow a portion of the light's spectrum to be recorded while blocking out other areas. For instance, a red filter lets an object's red light pass through to the CCD, while keeping out the green and blue light. Typically, the RGB filters used for astroimaging are Wratten #25 red, #58 green, and #47 blue. The transmission rates of these filters should be high (85% or better) so that CCD exposures can remain as short as possible. It's also important for the filters to have sharp, well-defined cutoff regions so that blue light passes through the blue filter only and not through a portion of the green filter, for example.

In addition to the RGB filters, an infrared exclusion filter is needed because unlike film, a CCD is sensitive to the infrared wavelengths of light. An infrared filter blocks the infrared light that would otherwise contaminate each of the red, green, and blue exposures. Finally, I recommend using a transparent filter to make locating objects and focusing the CCD camera easier. A complete set of 1.25" screw-in filters (transparent, infrared, and RGB) can be purchased for about $150 and is available from many astronomy suppliers (see the ads in this magazine). Make sure that the filters you buy are each the same thickness or else the CCD camera will have to be refocused after each filter change.

As tricolor imaging became popular among amateur astronomers in the early 1990s, a number of methods developed for exchanging filters without disturbing the CCD camera or telescope. One of the most popular devices to emerge is something called a color filter wheel. This wheel holds a set of screw-in 1.25" or 2" filters on a rotating disk so that you can easily make changes. Alternatively, you can use a color filter slide that allows filters to be moved back and forth as needed. I've seen homemade and commercial versions of these devices (manual, electronic and even computer-controlled). If you prefer devices that are simple, easy to use, and inexpensive, you may want to try the "filter adapter slot" from Van Slyke Engineering, which accepts manually placed filters and can be used with any CCD camera. All filter holders allow the infrared filter to be held in place for each exposure (typically at the nosepiece) while the RGB filters are changed to produce the three frames.

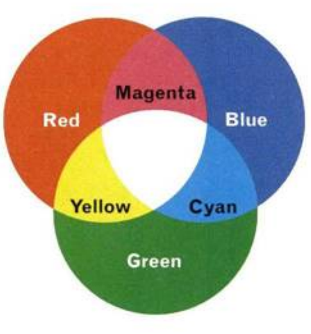
A color filter wheel, color filter slide, or filter adapter increases a CCD camera's distance from the telescope, termed its in-travel. This can be troublesome to certain telescope designs such as a Newtonian. If your telescope has a small amount of in-travel, you may want to consider a CCD camera with an internal, self-contained color filter wheel. An internal wheel has the benefits of adding zero in-travel as well as being lightweight, inexpensive, and controlled with CCD camera software. Unfortunately, internal wheels must be designed into a CCD camera and cannot be added to every system. If you require an internal wheel, be sure to check with your dealer before making a purchase.

COLOR FORMATS AND APPLICATIONS

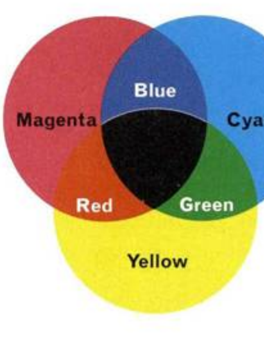
RGB: The RGB color model is made of three additive primaries, red, green, and blue. It is called additive because the three different primaries are added together to produce a desired color. In this mode you start out with black (the absence of all colors) and add red, green, and blue light to make white. Nearly all digital devices work in RGB (scanners, monitors, etc.).

CMYK: To reproduce colors on paper, as you perceive them, a technique was developed that splits the RGB into cyan, magenta, yellow, and black inks. Known as subtractive color inks, these inks absorb certain wavelengths of light while reflecting others. This mode begins with white (which reflects all colors) and uses cyan, magenta, and yellow pigments to subtract reflected light to make colors. CMY colorspace is the theoretical opposite of RGB colorspace. The K, black, is not necessary but enables a richer black (central dot, below right).

Most Internet browsers support graphics in either the GIF or JPEG format. GIF is CompuServe's Graphic Interchange Format for compressing images. JPEG is an acronym for Joint Photographic Experts Group, the committee that established the standard. Because GIF files contain a maximum of 256 colors, they work well with solid flat colors, sharp edges, and line art. They also produce relatively small file sizes. JPEG files may contain as many as 16 million colors. They can be compressed significantly to produce easily transportable files.

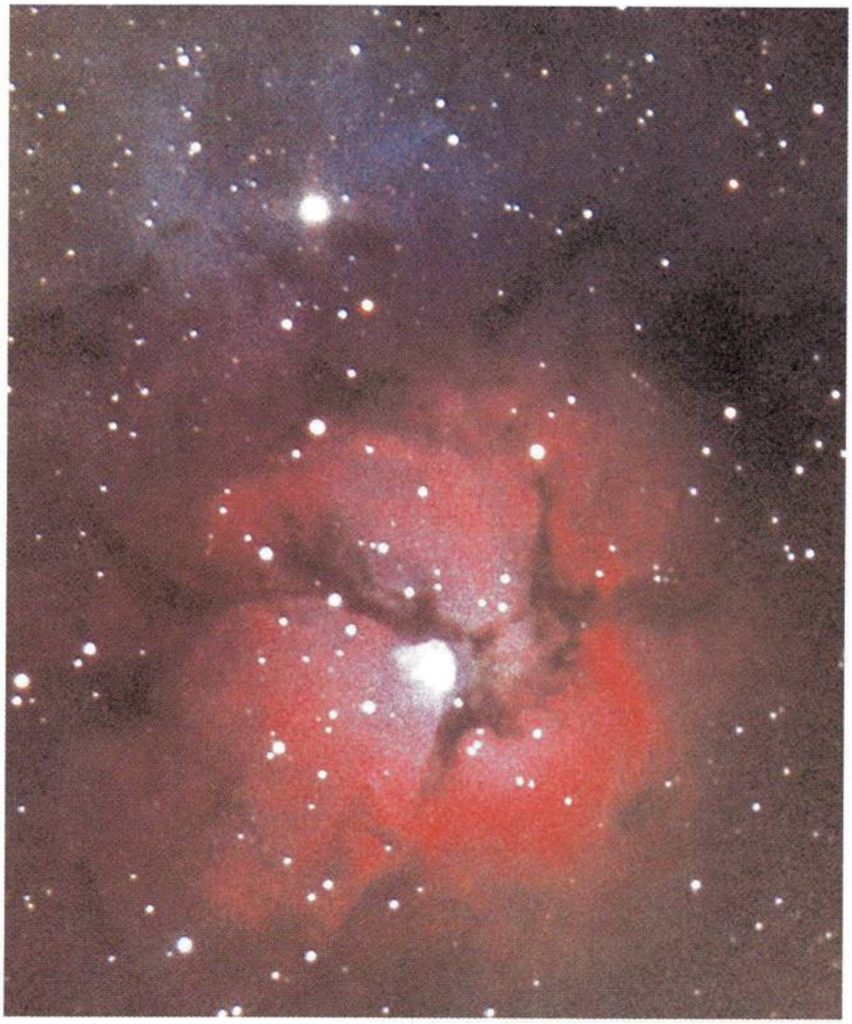


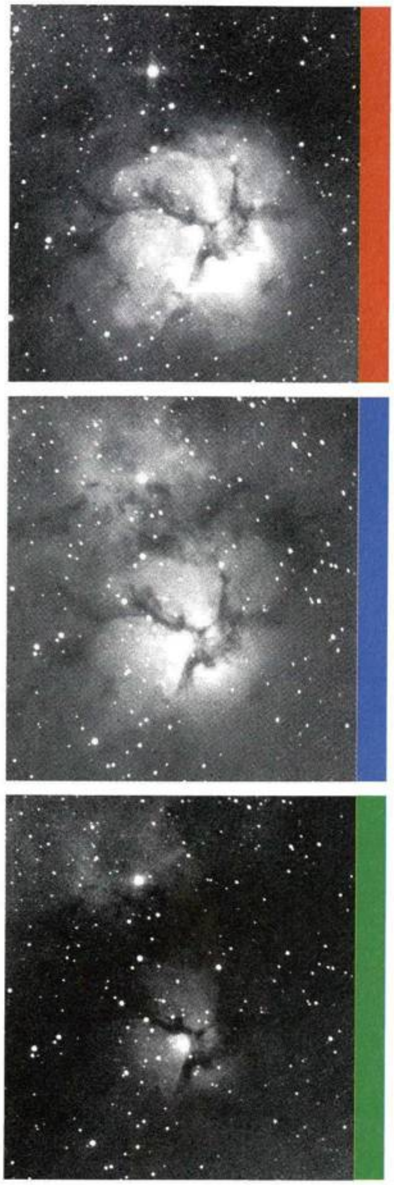
Additive Color Model (RGB)



Subtractive Color Model (CMYK)

CREATING A TRICOLOR COMPOSITE IMAGE





CCD technology doesn't allow a one-shot color photo. Instead, astroimagers need to shoot identical exposures of the same object through different filters — red, green, and blue — and then assemble the image in an image processing program such as Adobe Photoshop. The blue frame (right center) should be exposed 2.8 times as long as the red shot (top right), and the green image (right bottom) 1.4 times as long as the red. David Hanon

Tricolor assembly requires software that can take three separate filtered images and composite then into one color image; fortunately, dozens of software packages can accomplish the feat. Many astronomers use multiple programs for tricolor work, one for acquiring and basic processing (often the CCD camera software itself) and another for advanced processing, color adjustments, and assembly.

The most popular graphics packages for tricolor image assembly include the image processing software Adobe Photoshop ("street price": $600), Corel Photo Paint ($300), Micrografx Picture Publisher ($109), and Paint Shop Pro ($99). Cyanogen's MaxIm DL ($299) and Bruce Johnston's MegaFix ($109) are designed specifically for astroimaging and tricolor imaging.

How to Capture a Tricolor Image

The complexities of exposure compensation, a CCD's sensitivity, and image processing techniques make acquiring color CCD images a difficult skill. The filters require longer exposures for each RGB image (filters reduce incoming light) and also different exposures for each (due to a CCD's variable sensitivity to different wavelengths of light). If you've captured black-and-white digital sky images, you've already mastered many of the techniques needed for tricolor work such as finding, focusing, and guiding. These skills will serve as stepping-stones to successful tricolor CCD imaging.

Each tricolor exposure (red, green, and blue) has to be adjusted to offset a CCD's varied sensitivity to light. For example, consider the Kodak KAF–0400 chip. The KAF–0400 is slightly more sensitive to red light than it is to green; its blue sensitivity, on the other hand, is notoriously limited. Adjusting exposures for each filter will make up for these differences. Longer exposures are required for the less sensitive areas of the CCD.

Bright deep-sky objects such as the Dumbbell Nebula (M27) make good starting targets for tricolor experiments. A commonly used telescope, such as an 8-inch f/5 reflector or an 8-inch f/6.3 SCT, can capture much of M27's nebulosity

Jack Newton

CCD cameras can capture the intricate details of faint nebulae like the supernova remnant IC 443 in Gemini (opposite page) and the challenging Horsehead Nebula in Orion (right). IC 443: David Hanon

with a 120-second red exposure and a KAF–0400 based CCD camera. After adjusting for the chip's sensitivity, a green exposure with the same camera would be 168 seconds and the blue exposure, a lengthy 336 seconds. A typical set of filtered exposures for KAF–0400 CCD would be red = 1.0x, green = 1.4x, and blue = 2.8x. These ratios ensure that the final image appears reasonably well balanced, providing a good color representation of the original object. The actual compensation factor needed depends on many conditions, primarily the CCD chip and the RGB filters.

Tricolor planetary imaging adds another challenge. Because planets rotate, a set of tricolor images has to be grabbed quickly or surface details will not match up properly between the red, green, and blue exposures. Saturn, one of the planets most photographed in color, is the least susceptible to rotation problems since its surface markings are very subtle; Mars and Jupiter, however, show surface details that are readily detectable with an 8-inch telescope. Both planets rotate quickly (0.25° and 0.6° per minute, respectively). A good rule of thumb is to obtain a set of red, green, and blue images within 5 minutes of each other so that surface markings can be matched well.

I begin tricolor planetary imaging with the red filter in place. Red images not only show the most detail, they also serve as a basis for the green and blue exposures. Once one or more high-quality red images are taken and saved, switch to the green filter (with the appropriate exposure adjustment), and then finally to the blue filter. It's best to attempt to grab as many good red, green, and blue images within a short time frame as conditions allow. Afterward, you can sort through the best to create a single tricolor image. As with all planetary photography, the trick is to take many exposures and save only the sharpest images snapped during moments of atmospheric steadiness.

TRICOLOR FILTER EXCHANGING

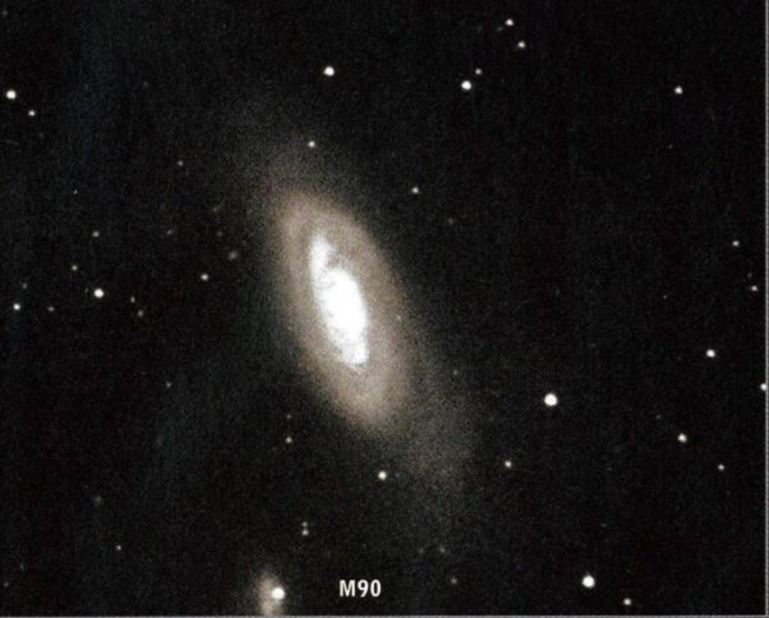
Manufacturer	Description	List Price
Celestron	Internal wheel for the PixCel CCD cameras (only)	$350
Homeyer	Wheel for any camera	$475
ISI Systems	Wheel for any CCD camera	$1000 to $3000
Meade	Wheel for any CCD camera	$1290
Murnaghan Instruments	Wheel for any CCD	$500 to $1500
Van Slyke Engineering	Wheel for any CCD camera	$995 to $2995
	1.25" and 2" color filter adapter slots for any CCD camera	$99 to $139
SBIG	Wheel for SBIG cameras (only)	$849

Putting It All Together

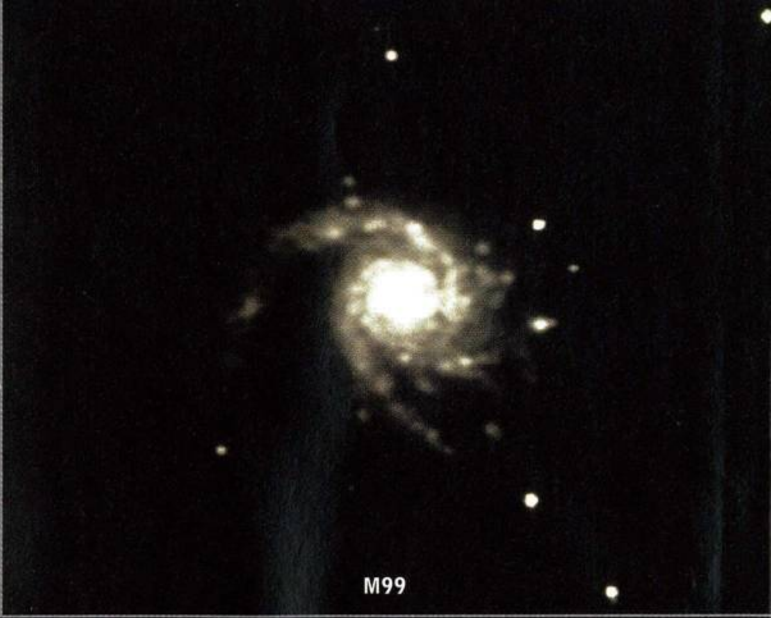
Assembling three filtered images into a single color image is amazingly straightforward with the software currently available today; of course, the actual process follows the particular software package you buy. After the filtered images are carefully processed, they are "cut and pasted" onto the appropriate red, green, or blue layer and combined into a single RGB image. Each image should be processed identically in terms of contrast, brightness, and sharpening to maintain good color balance. The individual images will have to be moved in order to match-up or register with each other. In Photoshop, each layer can be moved with the arrow keys, one pixel at a time, so that they register perfectly with each other. Because each program handles object movement differently, the actual keystrokes will vary, but they use the same idea — to place each layer precisely on top of the others.

Registering deep-sky images is made easier by zooming in on and viewing individual stars. One image (say the red) remains fixed during this process, and the other two images (green and blue) are moved to match it. When each image is aligned, stars will appear to be white, with no color fringes. Advancing to tricolor imaging is a natural progression for any astronomer with some experience in black-and-white imaging; all that is required is a set of filters, a filter holder, and some software. Fortunately, many software and hardware products offer the capabilities. Using skills sharpened with black-and-white CCD imaging, digital color images are just a few extra keystrokes away. ■

Gregory Terrance is an avid astroimager whose multipart series is covering the basics of CCD astronomy.



M90



M99

Into the Realm

M61

M88

M100

# of the GALAXIES

The Virgo Cluster offers a thousand targets for galaxy hunters.

by Phil Harrington

Springtime finds our window on the night sky turned away from the obscuring dust and star clouds of the Milky Way, revealing thousands upon thousands of galaxies floating like islands in a vast ocean. Seemingly wherever you turn, a galaxy awaits the penetrating stare of a telescope.

But the distribution of galaxies in the spring sky is far from uniform. Although some seem to be isolated systems, most clump into bunches.

M61 by Jack Newton; M90 by Martin C. Germano; M99 by John Chumack and Glenn Gombert; M88 by Kim Zussman; M100 by Dale E. Mais

Some groups hold only a handful, others contain a dozen or so, but the largest concentration holds more than 1,000 individual galaxies and spans more than 100 square degrees along the border between Virgo and Coma Berenices. Astronomers refer to this gathering as the Coma-Virgo Cluster, or more poetically as the Realm of Galaxies. The members of this Realm lie an average of 50 million light-years from the Milky Way Galaxy, which itself seems to be an outlying member of the even larger Virgo Supercluster.

Hundreds of Realm members can be seen through a typical backyard telescope, with the brightest visible even in steadily held binoculars. In fact, if you casually aim a 6-inch or larger telescope somewhere between the stars Denebola (Beta [β] Leonis) and Vindemiatrix (Epsilon [ε] Virginis), you're bound to bump into a galaxy. The only problem is in figuring out which one you bumped into. In this visitor's guide, we'll attempt to attack the Realm a little more systematically.

GETTING STARTED

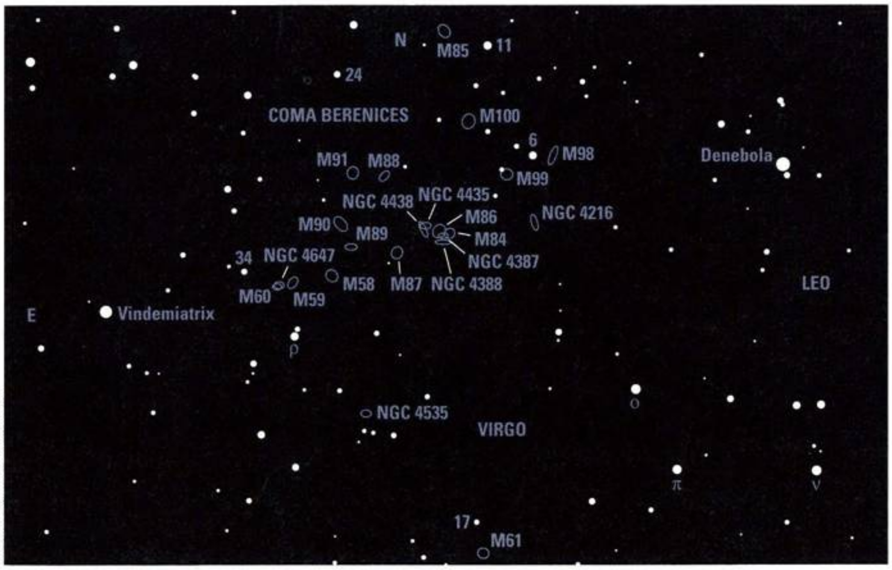
Let's begin at Denebola. Slide about 6° due east to the 5th-magnitude star 6 Comae Berenices, the brightest and westernmost point in a diagonal line of four stars that stretches toward the northeast. Our first target lies about half a degree west of 6 Comae. Cigar-shaped **M98** (NGC 4192), a nearly edge-on Sb spiral, shines at magnitude 10.1 and resembles a thistle of grayish light in most backyard telescopes. You may see the galaxy's prominent, circular core, but little additional detail is visible in its spiral arms.

Look about halfway between the third and fourth stars in our line to find **M100** (NGC 4321), a face-on Sc spiral. Through most backyard scopes, this 9th-magnitude galaxy displays a circular disk that grows brighter toward the center. Some keen-eyed observers may also discern a subtle mottling to the disk's outer circumference.

M99 (NGC 4254) forms the southern vertex of a galactic triangle with M98 and M100, lying just southwest of a lone 7th-magnitude sun. Pierre Méchain discovered all three galaxies on March 15, 1781, and Charles Messier added them to his catalog less than a month later. A face-on Sc spiral nicknamed "The Pinwheel," M99 is bright enough to be seen through a 3-inch telescope or giant binoculars on a dark night. A 6-inch telescope can reveal one of the galaxy's spiral arms, though it takes an experienced eye to make it out. Look for the arm curving toward the southwest directly opposite the 7th-magnitude star. Spiral structure becomes quite apparent as telescope aperture grows into double digits.

From 6 Comae, drop 2° south for **NGC 4216**, which lies just across the border in Virgo. An edge-on Sb spiral, this 10th-magnitude galaxy displays a long, thin splinter of grayish light with a much brighter central region. If you use averted vision and moderately high magnification, you might be able to glimpse a dust lane passing along the eastern side of the core.

The elliptical galaxy **M85** (NGC 4382) lies about one-third of the way from 11 to 24 Comae. Shining at magnitude 9.2, it's bright enough to glimpse with steadily held binoculars under a rural sky. Telescopes both small and large show M85 as an oval, silvery blur that suddenly brightens to an intense stellar core. Be sure to look 7' to the east of M85 for NGC 4394, a smaller, fainter SBb barred spiral.



Astronomy: Elisabeth Rowan

From 6 Comae, leap past M99 to **M84** (NGC 4374) and **M86** (NGC 4406), a pair of bright elliptical galaxies that lies at the heart of the Realm. Only one-third of a degree separates M84 and M86 in the sky. Both feature bright cores enveloped in dim halos of unresolved suns. A casual observer might see both of these 9th-magnitude galaxies as identical, but a closer look shows M84, an E1, to be smaller and brighter while M86, an E3, appears slightly oval.

SEARCHING FOR FAINTER COMPANIONS

Several faint galaxies surrounding M84 and M86 lie within the grasp of a good 8-inch telescope. The challenging E5 elliptical **NGC 4387** is located just to the south while a little farther south is **NGC 4388**, an edge-on Sb spiral that displays a conspicuous stellar nucleus when examined at high power. Twelve-inch and larger telescopes may also reveal a hint of the dark lane slicing through the latter's galactic plane. Collectively, M84, M86, and NGCs 4387 and 4388 look a little like a giant intergalactic face: M84 and M86 are the eyes, NGC 4387 the nose, and NGC 4388 the thin mouth.

The unusual galactic pair of **NGC 4435** and **NGC 4438** lies just 20' east-northeast of M86. Leland Copeland, a popular deep-sky writer of the 1940s and '50s, nicknamed these "The Eyes." One look and I think you'll agree that they almost seem to be staring back at you. NGC 4435, the smaller and more northerly of the pair, is an E4 elliptical galaxy, while NGC 4438 is an edge-on Sa spiral. In photographs, the two appear to be interacting, apparently caught in a gravitational tug of war.

Another of the 16 Messier objects that call the Realm of Galaxies home lies 2° northeast of M86 and just southeast of a 9th-magnitude field star. The Sb spiral **M88** (NGC 4501) flaunts a bright nucleus that appears offset within the halo of its spiral arms. Vague hints of spiral structure can be seen, albeit with difficulty, through telescopes as small as 8 inches in aperture, but you'll need a 14-inch or larger instrument to see this subtle detail clearly.

Hop a little less than a degree east from M88 to arrive at **M91** (NGC

4548). This barred spiral galaxy appears fairly bright and large in 6- to 8-inch telescopes, although its shape is vague when first spied. Careful examination shows a brighter core elongated from northeast to southwest.

Drop to the south a bit more than 1° to find **M90** (NGC 4569), a highly elongated Sb spiral highlighted by an extended core. When viewed through a 6-inch or larger telescope at medium-to-high power, M90 reminds many observers of the Andromeda Galaxy seen through a finderscope or binoculars. The galaxy tilts almost due north-south, but because it lies nearly edge-on to our line of sight, the spiral arms themselves are difficult to make out visually regardless of aperture.

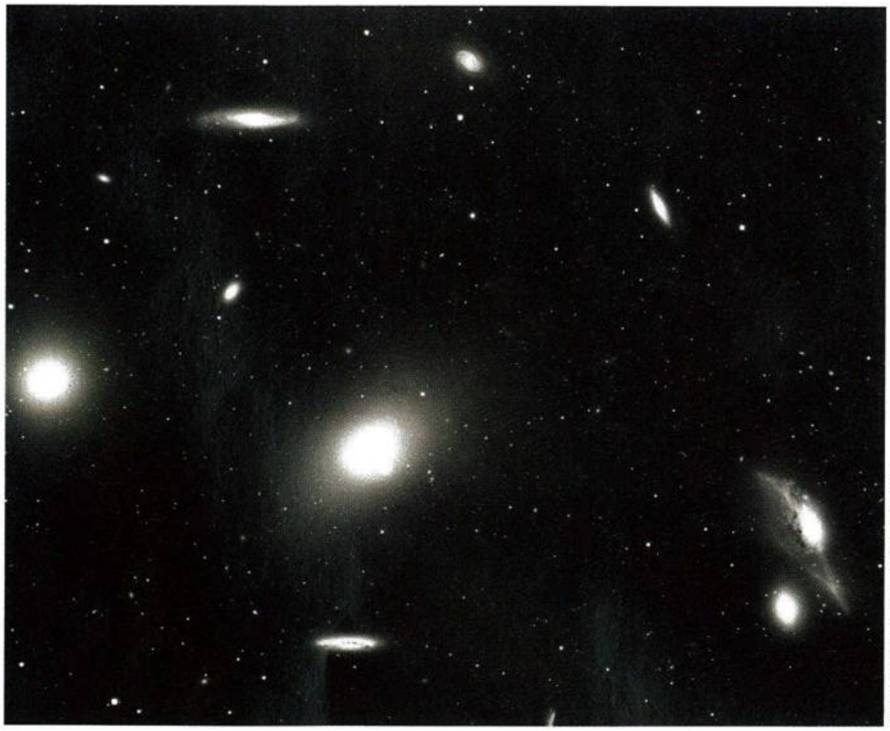
Our next stop lies in the same low-power field as M90, separated from it by an asterism of five 9th- and 10th-magnitude stars in a "W" pattern somewhat reminiscent of Cassiopeia. **M89** (NGC 4552) shines around 10th magnitude, about the same as M90, though it appears quite a bit brighter. This illusion arises because M89 covers only half as much sky as its neighbor. In contrast to M90's distinctly elongated disk, the E0 elliptical looks almost perfectly circular and boasts a distinct stellar nucleus.

VIRGO'S GALACTIC POWERHOUSE

One of the most intriguing galaxies in the Realm is **M87** (NGC 4486), located 1° west of an 8.5-magnitude star that lies just 13' southwest of M89. Backyard telescopes show this E1 elliptical's brilliant, not-quite-stellar core engulfed in a fainter, circular mist that fades slowly toward the edge. In 1918, Heber Curtis of Lick Observatory discovered a luminous jet emanating from M87's core. Later observations revealed that the galaxy also emits copious amounts of radio and x-ray radiation. In 1994 the Hubble Space Telescope indicated that all this activity stems from matter falling onto a supermassive black hole at the galaxy's center.

Return to M89, then veer about 1° southeast to **M58** (NGC 4579), an Sb spiral. Most amateur instruments show M58 as an oval disk highlighted by a brighter core, while 12-inch and larger apertures add an uneven, mottled texture to the halo.

M59 and M60 lie 1° east of M58. They appear about a moon's diameter apart, which lets them both squeeze in the same medium-power eyepiece field.


National Optical Astronomy Observatories

Two giant elliptical galaxies, M84 (left) and M86 (center), dominate the center of the Virgo Cluster. A close look at this region shows dozens of ellipticals and spirals.

M59 (NGC 4621), the western member of the duo, is an E3 elliptical galaxy that's an easy object in all but the smallest backyard scopes. Its distinctive, oval form shows off a brighter core that reminds some of M32, the brighter companion of the Andromeda Galaxy.

M60 (NGC 4649) appears both larger and brighter than M59; indeed, it is one of the brightest galaxies in the Realm and readily visible in finderscopes and binoculars. Small telescopes show this E1 elliptical as a bright sphere of starlight punctuated by a bright core. Before leaving the pair, take a moment to look for **NGC 4647**, a faint companion galaxy to the northwest of M60 that often goes unseen by observers even though it can be glimpsed in telescopes as small as 4 inches. You will find its dim core 1.5' from that of M60.

A TEST FOR BIG SCOPES

Our survey's only irregular galaxy lies 5° southwest of M59 and proves to be a real bonanza for large apertures under pristine skies. At first glance, **NGC 4535** seems little more than another featureless smudge, but closer inspection with a 10-inch or larger instrument begins to unveil a latent surface mottling. Some observers report a very subtle dark lane across the galactic plane between the brighter core and the galaxy's northern edge.

Our final stop on this whirlwind tour is **M61** (NGC 4303), found halfway between 16 and 17 Virginis. Barnabus Oriani, director of the Observatory of Brera in Milan, Italy, discovered this galaxy on May 5, 1779, while trying to observe the Comet of 1779. He described it as "very pale and looking exactly like a comet." Messier recorded it just six days later while viewing the same comet. As with most face-on spirals, M61 suffers from low surface brightness, causing many first-time visitors to pass right over it if they scan too quickly. Once you spot M61, switch to a higher magnification to reveal its dim, stellar core as well as a subtle mottling to the halo.

Our romp through the Realm may be over, but we have seen just the tip of a huge galactic iceberg that awaits deep-sky observers. I always look forward to clear nights in the spring so that I can plunge back into this celestial megalopolis to discover more new galaxies. Even after returning to the Realm over and over for more than two decades, I know that there are still new sights for me to see. Come join me this year and begin your own personal tour. ■

Phil Harrington is an avid observer living in Smithtown, New York. He reviews Vixen's giant binoculars on page 78 of this issue.

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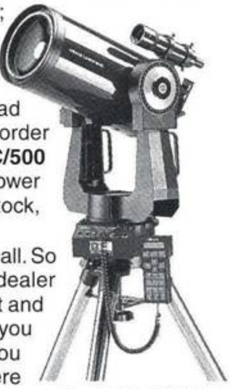

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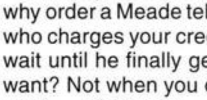

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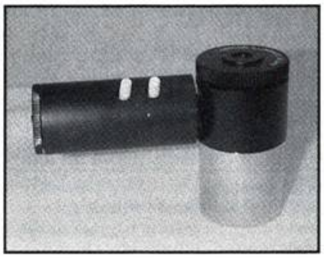

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12mm Nagler Type 4, 82° 1¼"or 2"	$340
16mm Nagler Type II, 82° 1¼"or 2"	$310
17mm Nagler Type 4, 82° 2" only	$370
22mm Nagler Type 4, 82° 2" only	$445
31mm Nagler Type 5, 82° 2" only	$595
2" Paracorr visual coma corrector	$235
3,4,6,8,10,14mm Radian,60° field	$228
15mm Panoptic 1¼", 68° field	$210
19mm Panoptic 1¼", 68° field	$240
22mm Panoptic 1¼"/2", 68° field	$280
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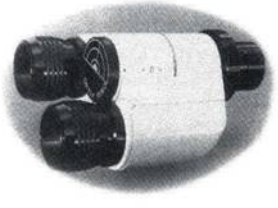
35mm Panoptic 2", 68° field	$365

Note: TeleVue warranty may not be valid outside USA

LUMICON® binocular viewer



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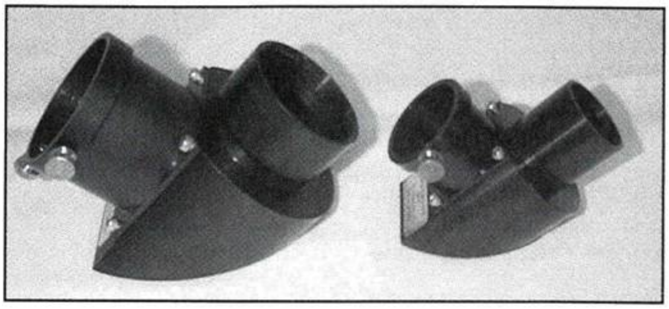

Too many amateur astronomers make a mistake! They purchase the refractor or Schmidt-Cassegrain of their dreams, add a great eyepiece and then join both with a cheap prism star diagonal.

Lumicon Star Diagonals have a 1/8th wave guaranteed mirror surface. Compare that to the 1/4th to 1 wave errors found in standard prism diagonals that come with today's telescopes. Enhanced aluminum coatings ensure bright images.

Perform your own test. At high power, try viewing through your scope with or without your star diagonal. If you can see a difference, you need a Lumicon Star Diagonal.

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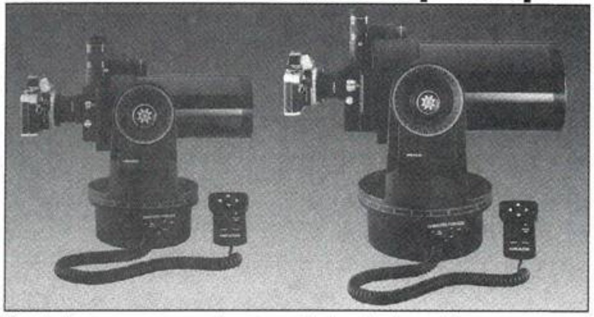
With 2"/1.25" reducer	**FREE** ($25 value)
Adapter for 2" diagonal to SCT	$29

Meade's New 'Table Top' Scopes



Meade instruments now has two choices in the table top computer controlled scope category. Maksutov optics deliver sharp, high-contrast views in both the 90mm and 125mm sizes. The optional Autostar computer creates an excellent astronmy classroom on a tabletop.

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LX50 – includes dec. motor, hand controller.
LX 200 - full computer control w/64k mem.
Tripod: Extra for LX 50; included for LX200

Note: Wedge is not needed for visual observing with the LX 200. Select f/10 or f/6.3 (no extra charge) for LX 200.

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*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing and shipping charge to the price. Slightly lower P&S for payment by check. Lumicon showroom prices are $50 to $100 higher.

See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.

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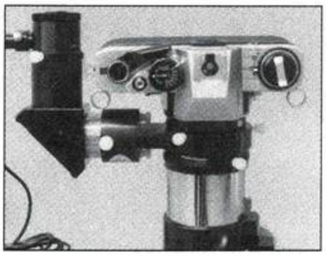
3 Choices of our Lumicon Easy Guiders ™



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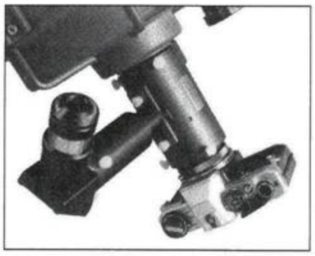
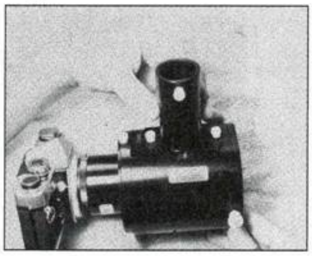
The **LUMICON NEWTONIAN EASY-GUIDER ™** is the best choice on the market for guiding both Newtonian and Refractor telescopes. Off-axis guiding is the surest way to get pin-point star images. The two-way adjustment on the off-axis tube avoids the problems of finding and centering a guide star in your eyepiece or autoguider. A 35mm camera adapter is included (specify camera). Available for either 1.25" or 2" focusers at **$189.50 each**



Cassegrain Easy Guider™

For 8" Schmidtt-Cassegrain telescopes choose the **LUMICON CASSEGRAIN EASY GUIDER™.** Includes mutiple adjustments for easily finding and centering a guide star and for composing the picture. The included internal 50mm focal reducing lens delivers brighter f/6 photographic images and can be used visually with an optional adapter. The lens can be removed for f/10 photography. A 35mm camera adapter (specify camera) is included.... **$249**

Visual Adapter **$25**



Lumicon Giant Easy Guider™

The king of off axis guiders is the **LUMICON GIANT EASY GUIDER™.** Made for Schmidtt-Cassegrain telescopes of 10" through 16" diameter, the giant easy guider attaches to the large 3" rear threads of these scopes. Included is an 80mm diameter focal reducing lens capable of delivering f/7 to f/4 photographic speed. Replacing the included 35mm camera adapter (specify camera) with a 2" star diagonal turns the giant easy guider into a full aperture rich-field viewer.......... **$395**

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STAR STUFF

PRODUCTS

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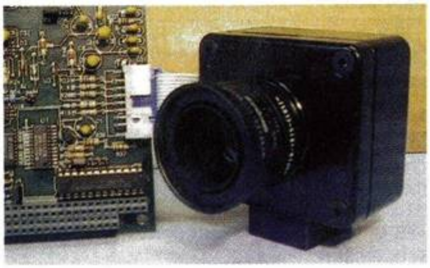
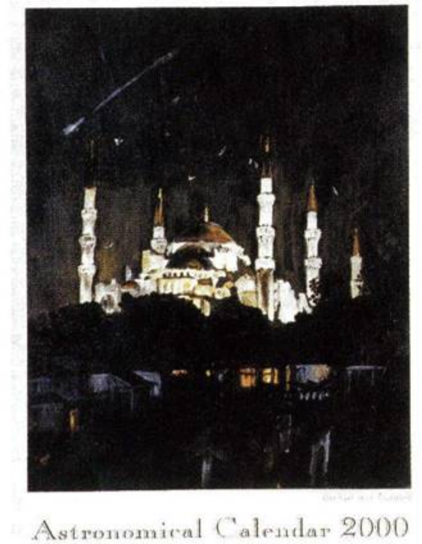


Supported operating systems include DOS, Windows 95/98, and Windows NT (Linux support is planned). All camera systems include an interface card, camera head, software, and a manual.

Electrim Corporation, 356 Wall Street, Princeton, NJ 08540; phone, (800) 683-5546; fax, (609) 683-5882; e-mail, info@electrim.com; website, http://electrim.com. EDC-1000 (192x165 pixels): *$400.* EDC-1000M (324x242 pixels): *$550.* EDC-1000L (753x242 pixels): *$800.* EDC-1000N (652x494 pixels): *$800.* EDC-1000E (652x494pixels): *$900.* EDC-1000U (1,134x486 pixels): *$1,250.*

PRODUCT INFO

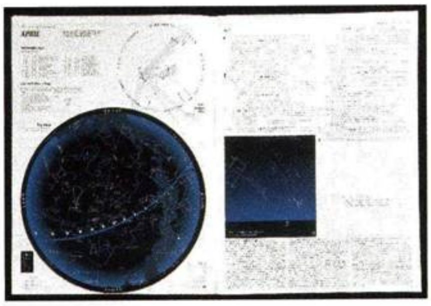
Suppliers should send announcements and color photographs to Star Stuff, P.O. Box 1612, Waukesha, WI 53187, or e-mail starstuff@astronomy.com. *Astronomy* assumes no responsibility for the product information supplied by manufacturers. Prices are retail and subject to change without notice. Check *Astronomy*'s website for further product updates — http://www.astronomy.com



The Astronomical Calendar 2000

▶ The *Astronomical Calendar*'s 80 pages are filled with useful diagrams, star charts, and information that not only includes astronomical facts, but a bit of history, mythology, and sky lore as well. Its large 11" by 15" format is easy to use and equivalent to three or four pages in an ordinary book.

Each monthly spread contains a sky map, clues to finding that month's constellations, a list of easy-to-find objects for telescopes or binoculars, a diary of events, and a horizon diagram that highlights a striking sky scene.



A supplementary glossary and sections on the sun, moon, eclipses, occultations, conjunctions, the planets, meteors, asteroids, and comets are also included.

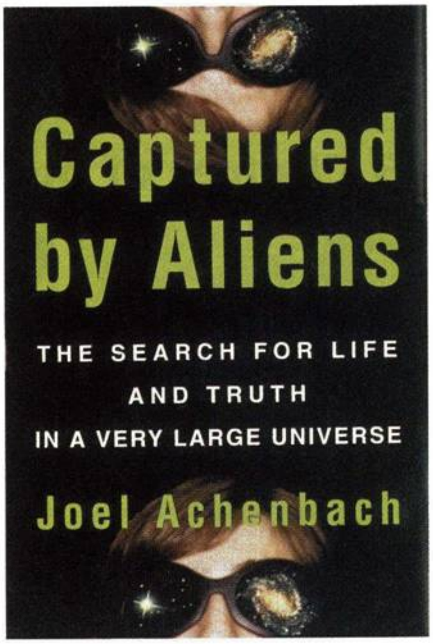
Universal Workshop, Furman University, Greenville, SC 29613; phone, (846) 294-2208; fax, (846) 294-3523; e-mail, guyvernon@aol.com; website, http://www.kalend.com. Astronomical Calendar 2000: *$22.*

BOOKS

Captured by Aliens: The Search for Life and Truth in a Very Large Universe

Joel Achenbach, 416 pages, Simon and Schuster, New York, 1999; ISBN 0-684-84856-2; hardcover, $25.

▶ We've all heard the saying "You can't judge a book by its cover." Most readers of *Astronomy* would look at the title of this book, *Captured by Aliens*, glance over the odd cover illustration, and then pass it by. It looks like just another one of those inventive tales of alien abduction by someone who is either delusional or has a get-rich-quick scheme. But the subtitle, *The Search for Life and Truth in a Very Large Universe*, gives a clue to the real story hidden within, a story of ambition, adventure, hopes, and dreams. It is a summary of the various ways people try to deal with the idea that life might exist on other worlds.



Achenbach, a writer for *The Washington Post*, relates his physical and mental journey to understand life, both here and its possibilities beyond Earth. He does not discriminate; interviewing established scientists and administrators such as Carl Sagan and Dan Goldin, along with those who believe they have made contact with aliens or are themselves aliens. From serious

got stars?

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SETI projects to the set of *The X-Files* and a circus-like meeting in Laughlin, Nevada, Achenbach explores every path that may lead to extraterrestrial life. And because there have been only dead ends at every turn, each path, whether it's perceived as crazy or scholarly, rests on a kind of equal footing.

The first half of the book concerns the work of Sagan. If you have read either of the recent Sagan biographies, this information will seem a bit repetitive. But when we distance ourselves from Sagan in the latter part of the book, Achenbach constantly posits what Sagan would have said or thought in different situations. "Throughout this enterprise Sagan has served as my spiritual guide," he writes, "because I knew that wherever I went, and whatever I investigated, he had been there already."

The second half of the book ventures into the far-out. A woman who believes she may be part alien confessed to Achenbach that humans are "so unevolved. I'm almost embarrassed to be human. Actually, I hope I'm not." In another incident Achenbach speaks with a man who has written a book that is part Bible, part alien encounter. Achenbach describes the author: "He was a smart guy living alone in a trailer park. He'd had massive headaches and severe illnesses. He couldn't breathe very easily, because of a respiratory problem whose origin I refrained from exploring. He blamed the ETs for his run of hard luck. . . . In his story the part that rang truest was the pain."

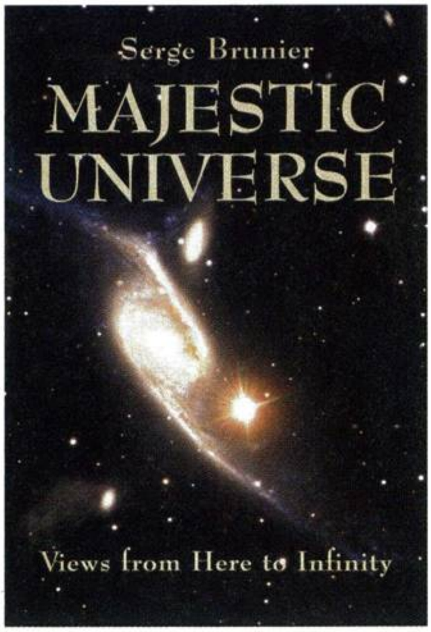
Achenbach portrays the perfect skeptic; he seems mostly interested in the motives behind what would make people believe things that seem so absurd to most of us. He gently points out the humorous and ironic side of the various situations he confronts. On his trip to Roswell, New Mexico, for the 50th anniversary of the supposed UFO crash, he relates the following encounter with one of the celebrants. "I ran into a man named Jim who had driven more than a thousand miles from Minnesota to commemorate the event. Jim, forty-one, a building official, took note of the carnival atmosphere and said, 'I think the serious side is being overlooked a little bit.' He said this even as he wore, on his head, a three-foot triangular aluminum-foil spaceship."

A complaint could be made that much of the material in the book presents old news: the Sagan mini-biography, the Mars rock ALH84001, the Heaven's Gate cult, and so forth. But Achenbach's first-hand experiences with the individuals involved and his relentless wit make every paragraph a pleasure. *Captured by Aliens* is a highly readable account of the ways humans contemplate life. Woven with sympathy and satire, this book is a pleasure in which to get lost. — *Kelly Whitt*

Majestic Universe: Views from Here to Infinity

Serge Brunier, 216 pages, Cambridge University Press, New York, 1999; ISBN 0-521-66307-5; hardcover, $39.95.

▶ More than 200 photographs, many of them from the Hubble Space Telescope, fill this large-format book, which will drive many to view it as a coffee-table book. But it's more than that. Thirteen chapters on categories ranging from a history of cosmology to missing mass and gravitational lenses organize the stunning images, and a generous amount of text educates and entertains those interested enough to stop and flip through it. Diligent readers of this book will come away with minds filled with the basics of astronomy and their eyes filled with stars.



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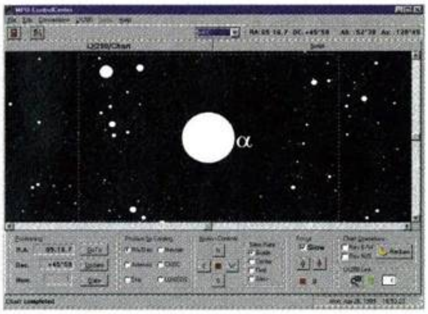

Get Connected

▶ The publishers of *The Minor Planet Observer* have introduced a software suite that aids hobbyists interested in automating their CCD-imaging sessions. Designed for use with the LX-200 and SBIG ST-7 or ST-8 camera, *Connections* allows the user to generate script that takes the telescope from target to target while snapping one or more images along the way. With more than 20 commands, the scripting language requires little direct entry.

For those looking to do asteroid astrometry, *Connections* holds an extensive database of asteroid elements. Just determine which asteroids you would like to image, enter their designations into the script, and let *Connections* do the rest.

If you're interested in charting asteroid and variable-star light curves, the CD holds a Fourier Analysis routine that crunches the data and helps determine the most likely period. *Canopus*, a full-featured astrometry and photometry program, is also included.

Minimum system requirements: IBM compatible 386MHz computer (486-66 or Pentium recommended); Microsoft Windows 3.1 (Windows 95 recommended); 800x600x16 screen resolution (1024x786X256 recommended); 1x CD-ROM (4x recommended); 8MB RAM (16MB recommended).

The Minor Planet Observer, BDW Publishing, 17995 Bakers Farm Road, Colorado Springs, CO 80908; phone, (719) 481-0557; fax, (719) 481-0833; e-mail, brianw_mpo@compuserve.com; website, http://home.turbopower.com/~brianw. MPO Connections: *$129*

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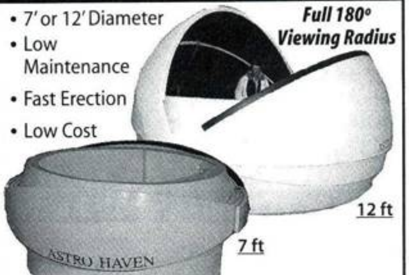

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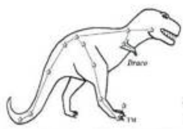

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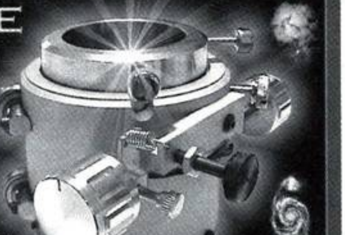

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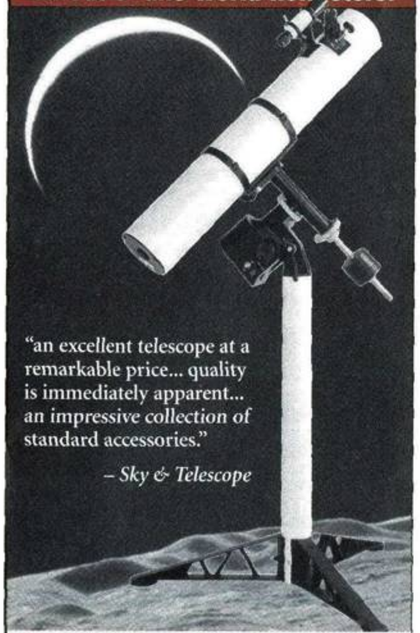

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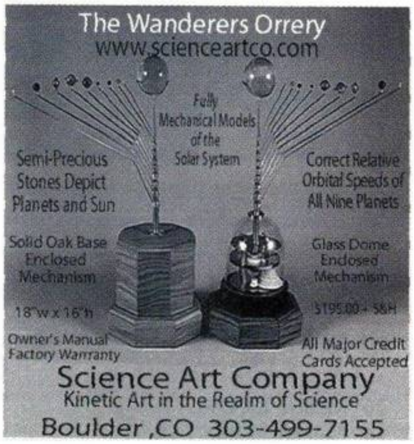

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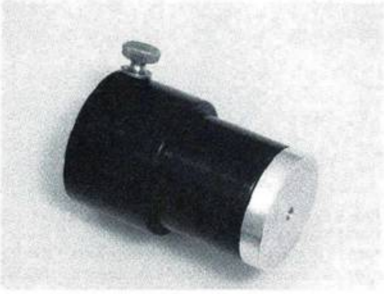

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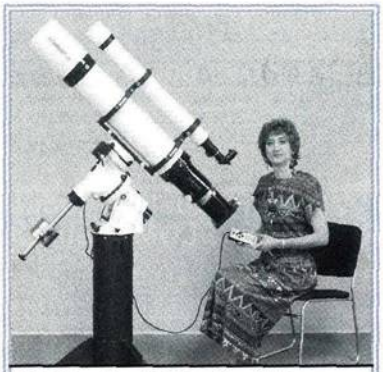

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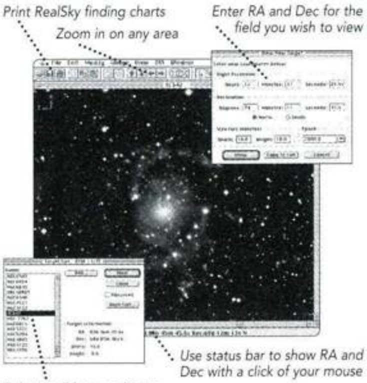
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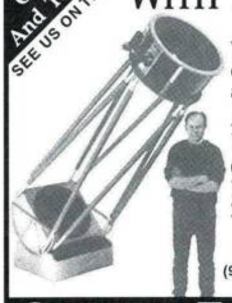

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Atlanta Astronomy Club's **Peach State Star Gaze** (PSSG) ranks as one of the largest gatherings for beginner and amateur astronomers in the southeastern United States. Its Year 2000 (**April 6-9**) session features guest speaker and lunar expert, Antonín Rükl of Prague, Czech Republic, author of *Atlas of the Moon*, in his only U.S. appearance. Mr. Rükl is the current vice president of the International Planetarium Directors Conference and former head of the Planetarium Prague, where he worked for 39 years. Planners set the event for a waxing crescent moon weekend in order to include early-evening lunar observing, which also allows for deep-sky observing later in the evenings. The PSSG is held each year at Indian Springs State Park's Camp McIntosh, just south of Jackson, Georgia, about midway between Atlanta and Macon. Preregistration required.

Contact Ken Poshedly, 1741 Bruckner Court, Snellville, GA 30078-2784; (770) 979–9842; e-mail, ken.poshedly@mindspring.com; website, http://aac.cjb.net.

MARCH 31-APRIL 2

Telescope Optics Workshop

Bellingham, Washington. This year's focus is on Maksutov-Newtonian Telescopes. Contact Kreig McBride, 402 East Horton Road, Bellingham, WA 98226; e-mail, kmcbride@memes.com; website, http://www.wwu.edu/~skywise/optics.html.

MARCH 31-APRIL 1

Austin Astronomical Society's Central Texas Star Party

Held at Eagle Eye Observatory at Canyon of the Eagles Lodge and Nature Park. There is no registration fee, but participants must pay park admission fee. Contact Anne Adkins, (512) 451-8895; e-mail, anne@hadkins.com. Eagle Eye Observatory or the Austin Astronomical Society; website, http://www.main.org/aas. For reservations at the Park Hotel, call 1-800-977-0081; http://www.canyonoftheeagles.com/.

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Northern lights and star trails highlight this star party near the Mogollon Rim in Arizona.

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APRIL 12

The Silicon Valley Astronomy Lecture Series

The Changing Sun and the Climate of the Earth, Smithwick Theater, Foothill College, Los Altos, California. 7 P.M. Free. Sponsored by NASA's Ames Research Center, Foothill College, the Astronomical Society of the Pacific, and the SETI Institute. Call (650) 949–7888 for more information.

APRIL 16

Northeast Astronomy Forum and Telescope Show

Rockland Community College, Suffern, New York. 9 A.M. to 6 P.M. Sponsored by the Rockland Astronomy Club. Contact Don Urban, (201) 768–6575 (eve.); e-mail, DonaldUrban@Juno.com.

APRIL 26-29

Mid-South Star Gaze

Rainwater Observatory and Planetarium, near French Camp, Mississippi. For information, (601) 547–6865 or visit http://rainwater.astronomers.org.

APRIL 29

Astronomy Day

Naugatuck Valley Community College, Waterbury, Connecticut. 10 A.M. to 5 P.M. Free. Sponsored by the Mattatuck Astronomical Society. For information, call (203) 575–8236.

APRIL 30-MAY 7

Texas Star Party 2000

Prude Ranch, Ft. Davis, Texas. For directions, e-mail tspreg@home.com.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or to cryback@astronomy.com. Look for additional events at http://www.astronomy.com.

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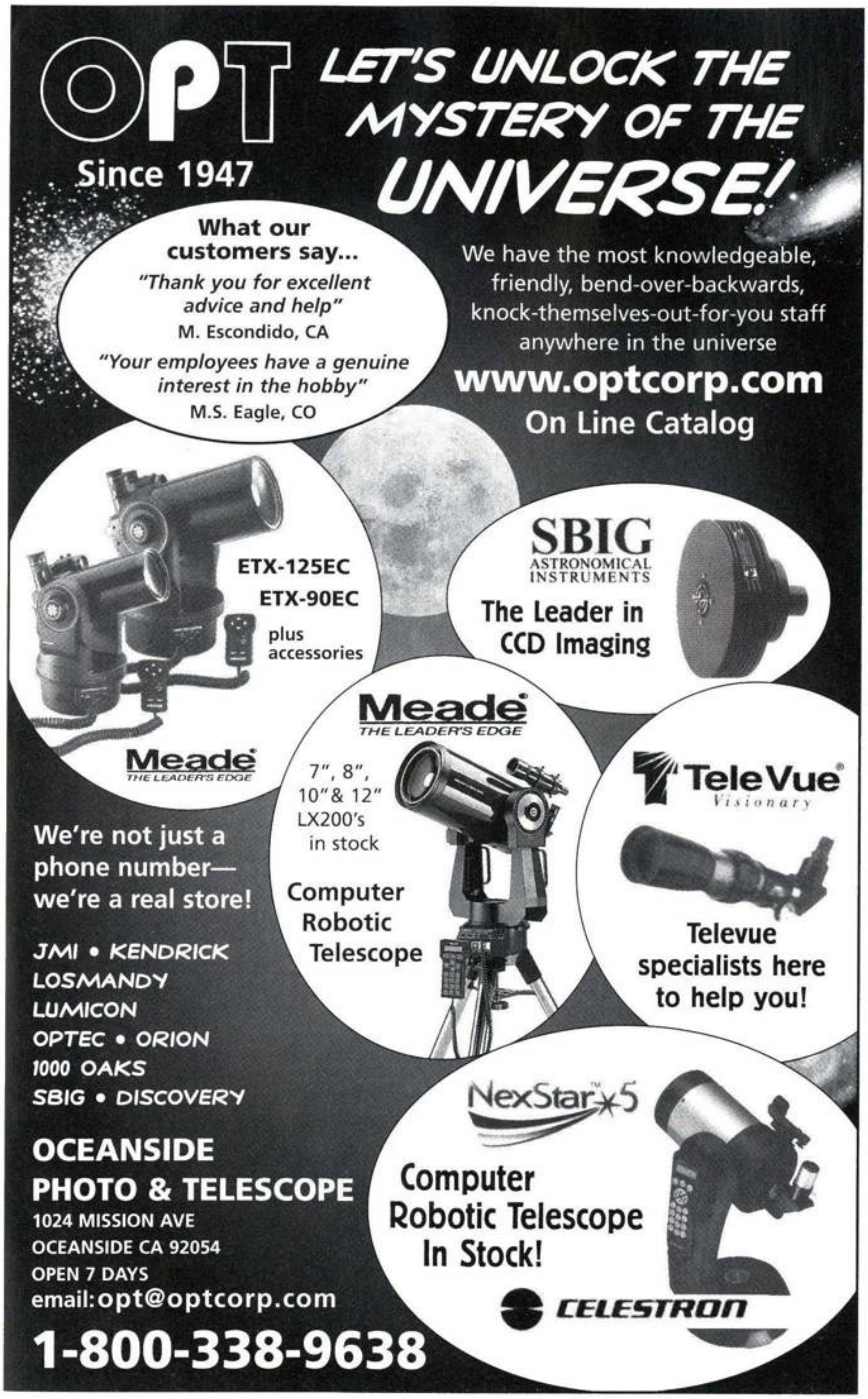

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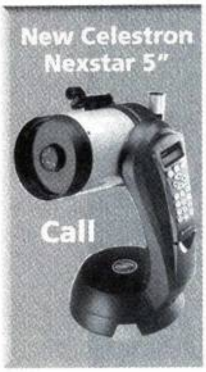

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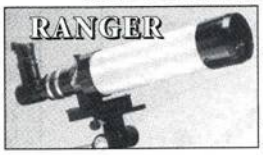

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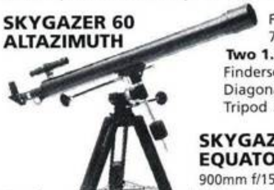

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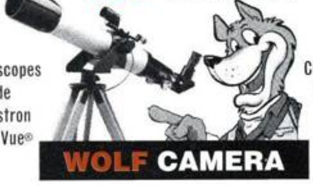

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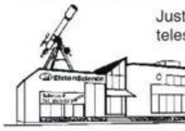

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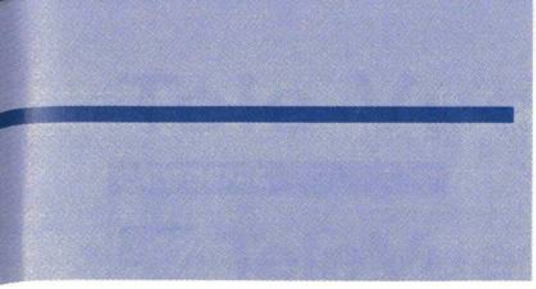

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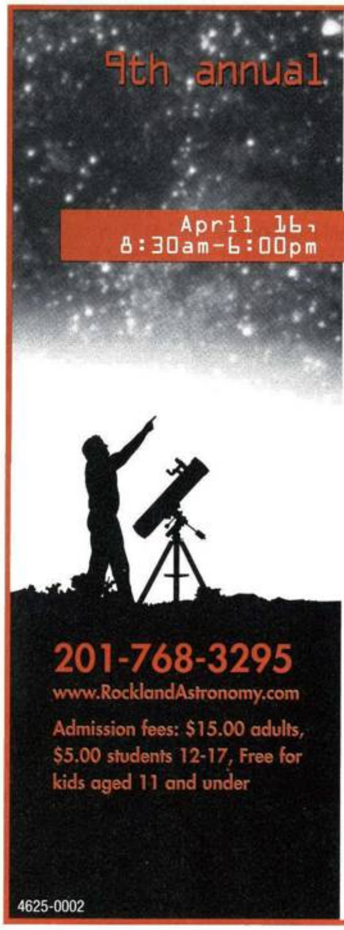

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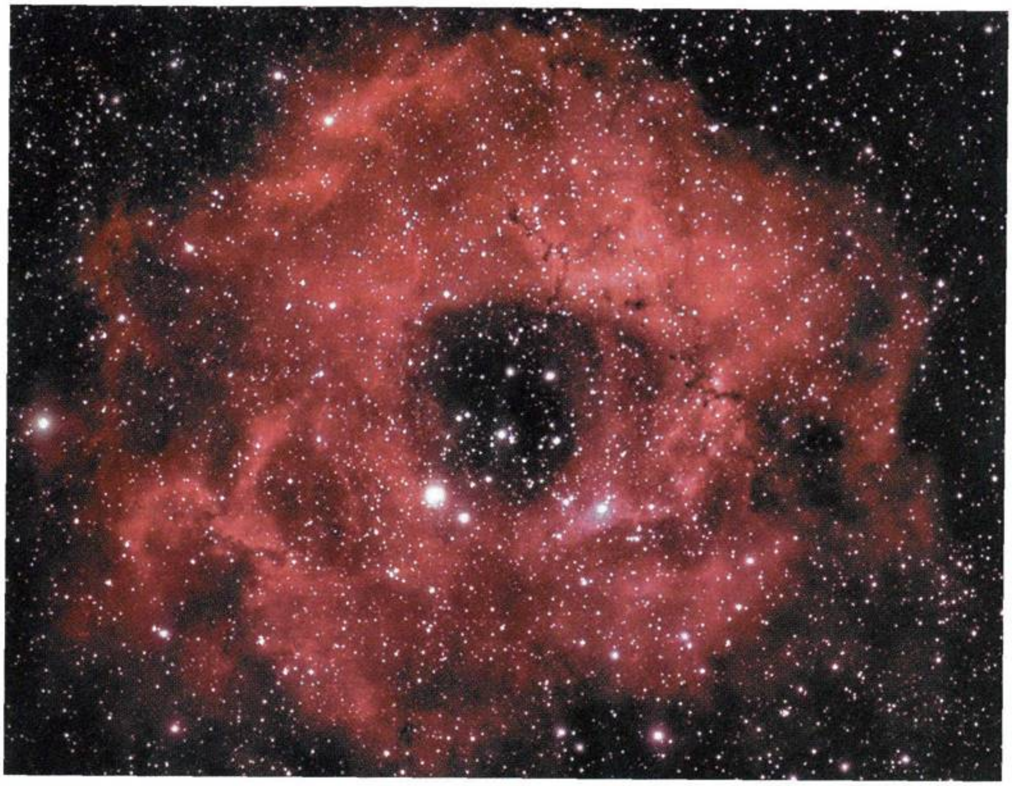
Seizing the Moment

A man from New Mexico records a unique evening.

▶ It was a warm and clear day, that last day of summer, 1999. During the afternoon the sky became threatening with thick, dark clouds flowing over the mountain ridges to the south of "Stern Wald," or Star Forest, our newly acquired cabin sanctuary in south-central New Mexico's Sacramento Mountains. As sunset approached, however, the clouds dissipated, and dusk had a wonderfully clear sky. The moon, three days until full, was already above the eastern horizon.

I sat on the picnic-table bench sipping a cool drink and watching the deepening twilight settle upon the forest of ponderosa pines. Eventually, I went into the cabin to bring out my trusty homemade telescope. As I carried the telescope tube from its resting place in a back room of the cabin, I happened to glance out the window. There, through a cluster of pine needles, I spied a bright object in the evening sky. What could it be? No celestial object should be there, and shining so brightly.

Hastily, yet carefully in order not to jar the delicate alignment of my scope's optics, I set up the 8-inch Dobsonian telescope out in the clearing. Then, with heart pounding, I dashed back into the hut to fetch my binoculars. Once outside, allied with optical reinforcement, I trained the



Rosette Nebula (NGC 2244)

ROBERT GENDLER

(6-inch refractor at f/5, ST8E CCD camera, composite of 10-minute red, 10-minute green, and 10-minute blue exposures)

Pinwheel Galaxy (M33) (below)

GEORGE GREANEY

(14.5-inch f/7.65 Ritchey-Chrétien telescope, hypered 35mm Kodak PPF Pro 400 film, composite of three 45-minute exposures)

Crab Nebula (M1)

JACK NEWTON

(16-inch SCT, Pictor 1616XTE CCD camera, composite of 5-minute red, 10-minute green, and 20-minute blue exposures)

Nova Aquilae 1999 Number 2

JEFFREY PETTITT

(70mm lens, Kodak 800 film, 10-minute exposure taken December 8, 1999)

Barnard's Loop (Sh 2–276) (below)

JERRY LODRIGUSS

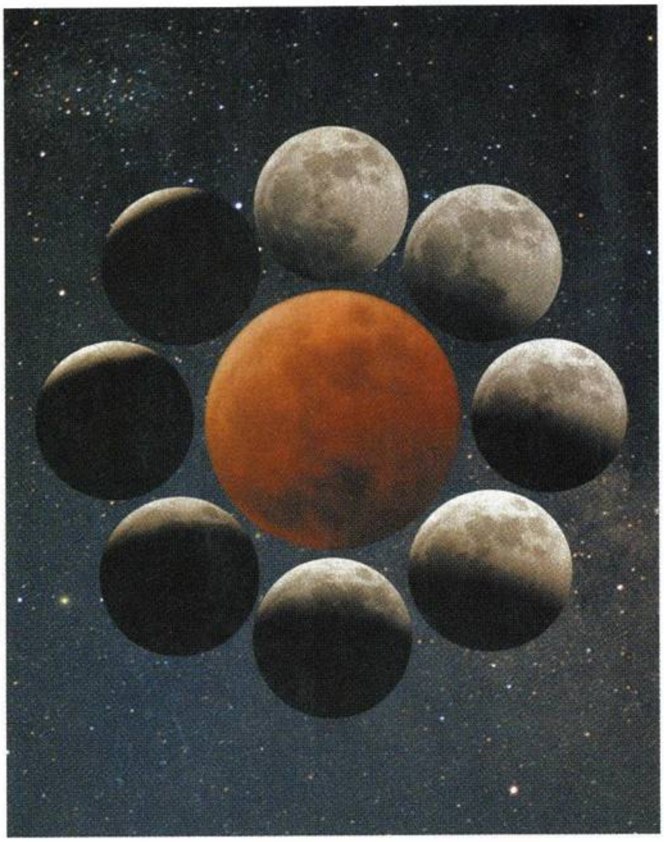
(500mm lens at f/4, composite of two 30-minute exposures on unhypered Kodak PJM film with a Deep-Sky filter and two 10-minute exposures on unhypered Fujicolor Super G 800 Plus film)

binoculars on the dazzling object high above the western horizon.

It was no great surprise that I immediately identified the object as a balloon, for I had seen them before. Placing a lawn chair next to the telescope's eyepiece, I focused on the intruder. A gossamer bag of gas in the shape of an elongated, inverted teardrop with a slender, barely visible thread connected to a gondola or payload was too small for me to determine any detail or discover if it was manned. Actually, only the part of the appendage close to the balloon was visible. Thus far not too unusual.

The already-set sun was still illuminating the apparition. It was far brighter than any star. Since it would still be a while before the sky would be dark enough for my evening's observing, I decided to keep watch on my companion as long as possible. At similar past opportunities, the balloon would disappear as the sun progressed farther below the horizon and could no longer shed light on the high-altitude ray catcher.

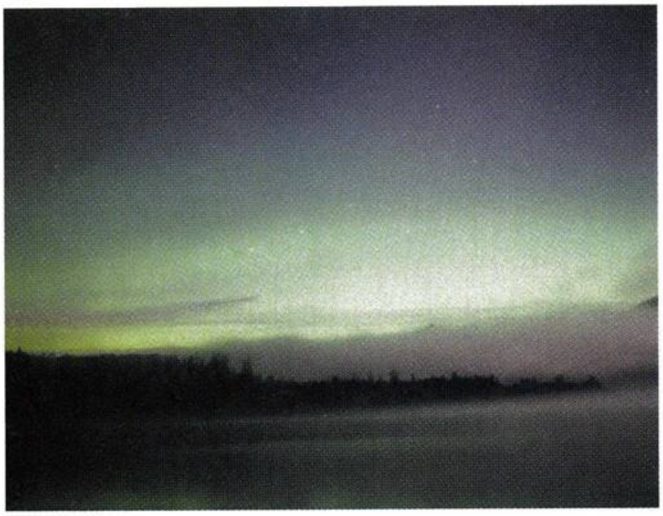
Tonight, however, there was a moon in the sky. Therefore, the balloon dimmed only to a certain low luminosity, then remained visible, lighted by Earth's natural satellite. And then, beside the gas bag appeared stars. The relative motion between the balloon's small eastward drift and the westward motion of the stars caused by Earth's revolution made for a surreal effect of the balloon drifting like the starship *Enterprise* flying past a background of stars. As the sky darkened further, more stars appeared, heightening the effect. The balloon was



Lunar Eclipse Mosaic

DAVE AND ROBERT CUNNINGHAM

(Eclipse phases by Dave Cunningham. 8-inch SCT at f/6, Kodak 400 film, 1/125-second exposure taken March 23, 1997. Totality by Robert Cunningham. 200mm lens at f/5.6, 1/30-second exposure taken September 26, 1996)



Aurora and Fog

WADE B. CLARK, JR.

(28mm lens at f/1.8, Fuji Super G Plus 800 film, 50-second exposure taken November 7, 1998)

scarcely moving. It took a full four minutes to drift from left to right through my 95x field of view, whereas the stars moved much faster from right to left. As I gazed in awe, many stars drifted past the balloon, disappearing behind the gas envelope, then reappeared again — similar to lunar occultations, except that I was able to experience several a minute.

Then it occurred to me, what would happen if one of the stars drifted behind a cord connecting the gas bag to the gondola? Would it wink out for a brief instant? I watched quite a few stars do that very thing, but unfortunately I could notice no winking. Eventually I abandoned my vigil and commenced my planned observing schedule, with a memorable night already under my belt. ■

Walter Kaminski is a retired air traffic controller and has been active in astronomy since before Sputnik. He now resides in Carlsbad, New Mexico, and makes variable star estimates with homebuilt 8-inch and 10-inch Dobs.

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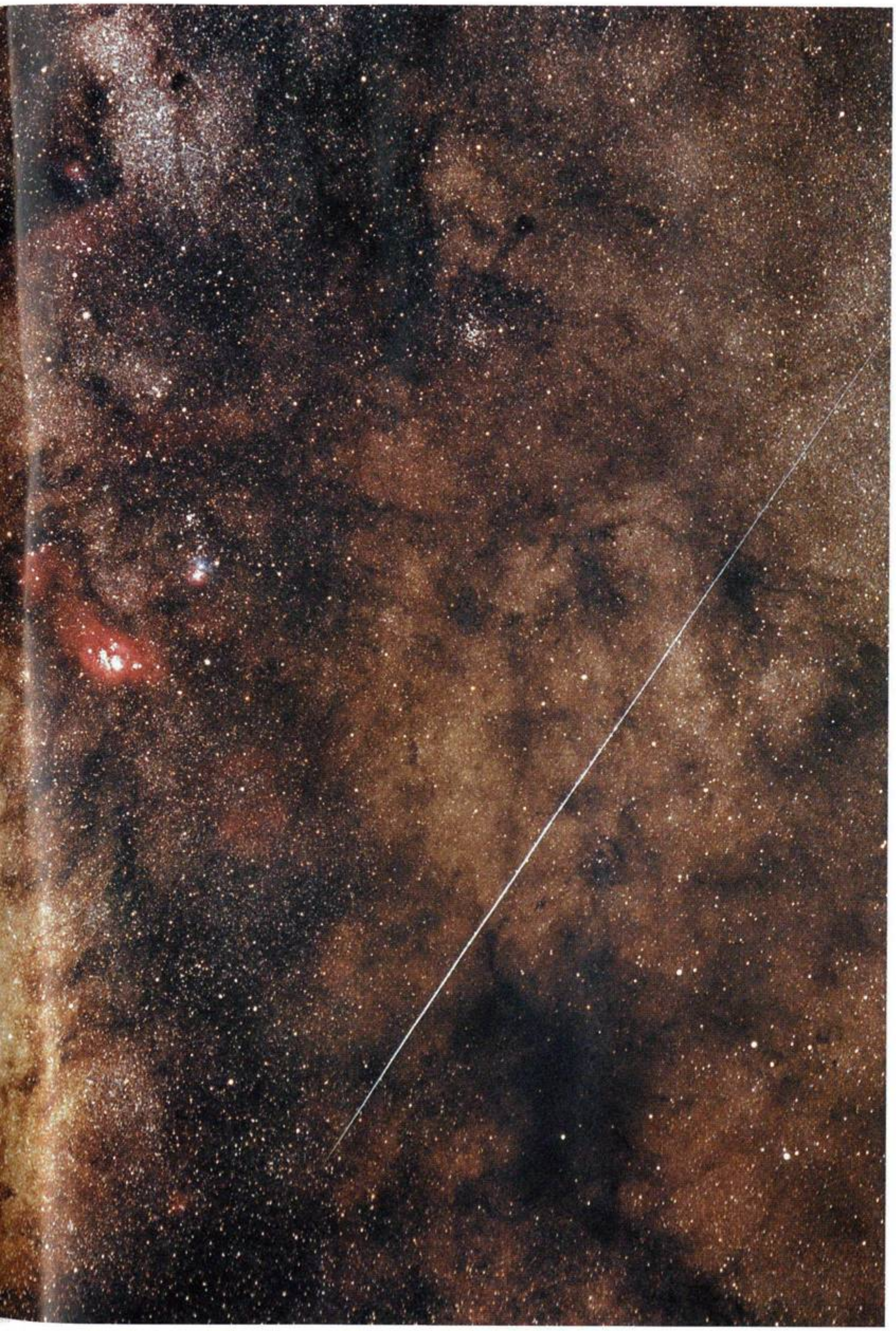
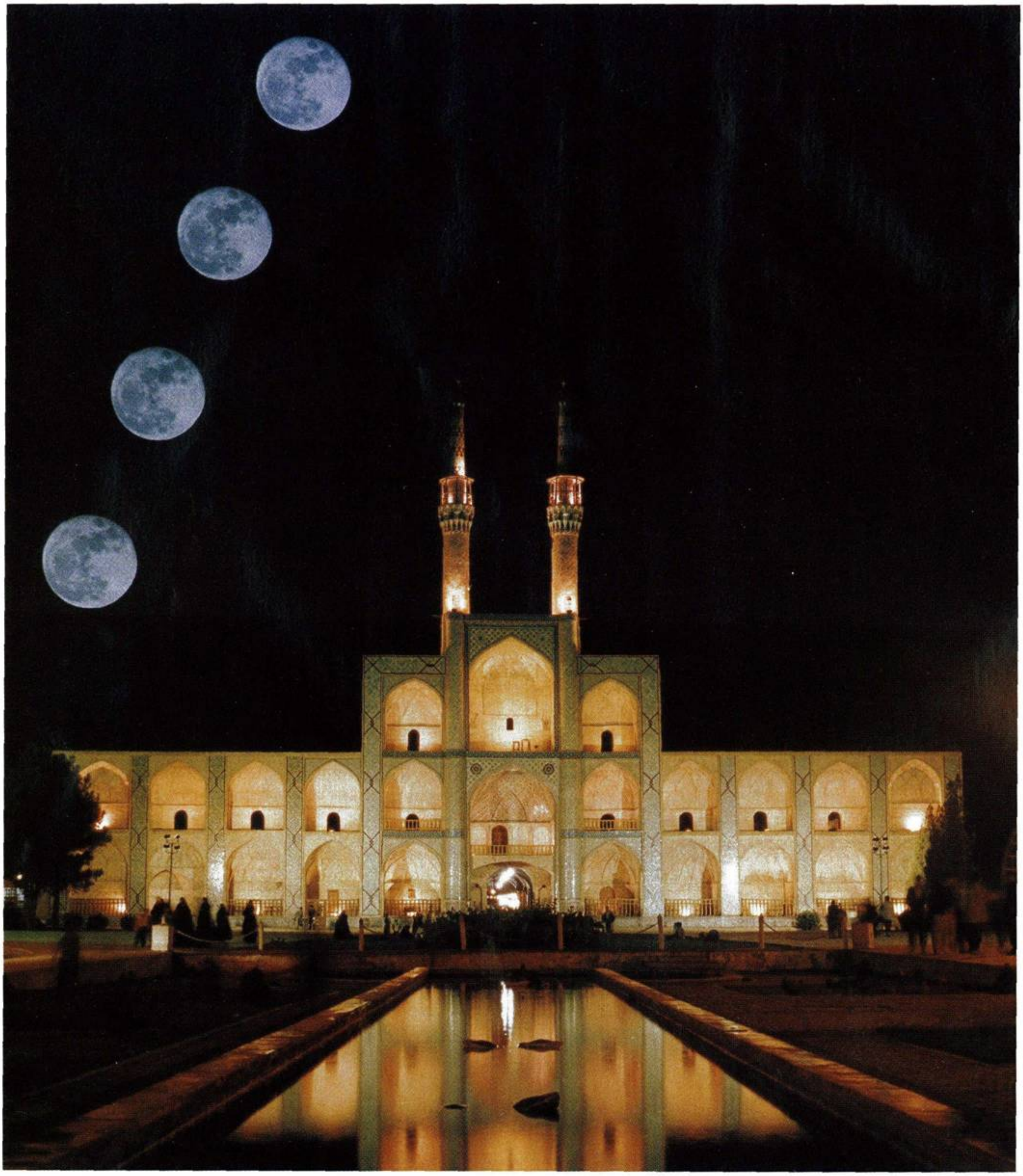


Meteor in Sagittarius

MIKE FIEST

(165mm lens, hypered Kodak PPF 120 film, composite of two 30-minute exposures taken in September 1999)

This month's best astrophoto



Moonrise over Tekeye-Mir-Chaghmagh

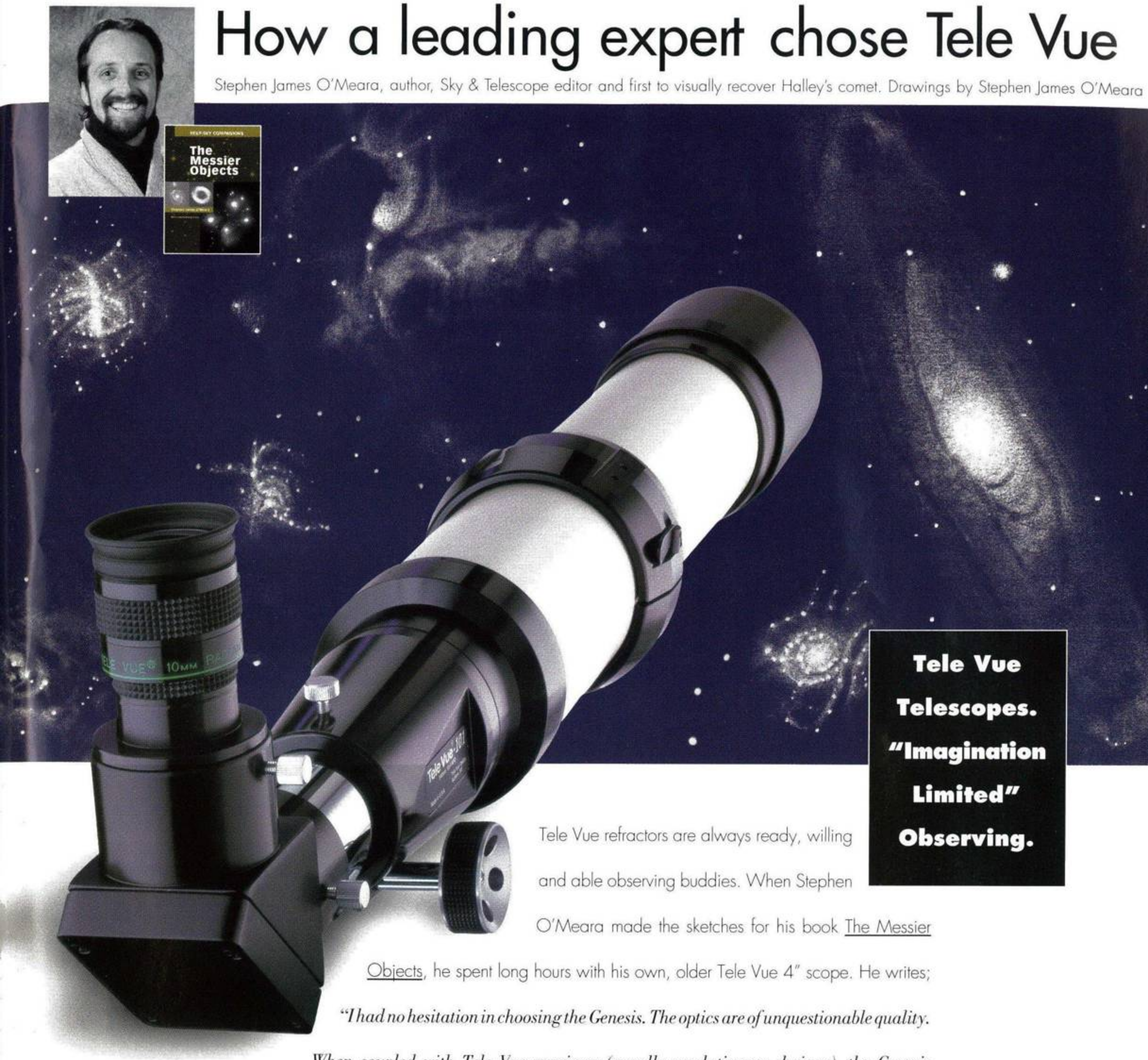
OSHIN D. ZAKARIAN

(Multiple exposure on Fuji Reala 100 film)

The full moon rises over the twin minarets of this bazaar entrance in Yazd, Yazd Province, Iran.

How a leading expert chose Tele Vue

Stephen James O'Meara, author, Sky & Telescope editor and first to visually recover Halley's comet. Drawings by Stephen James O'Meara



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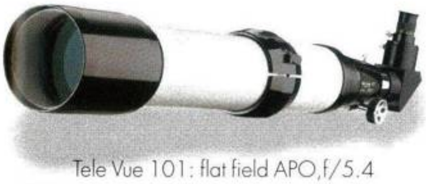

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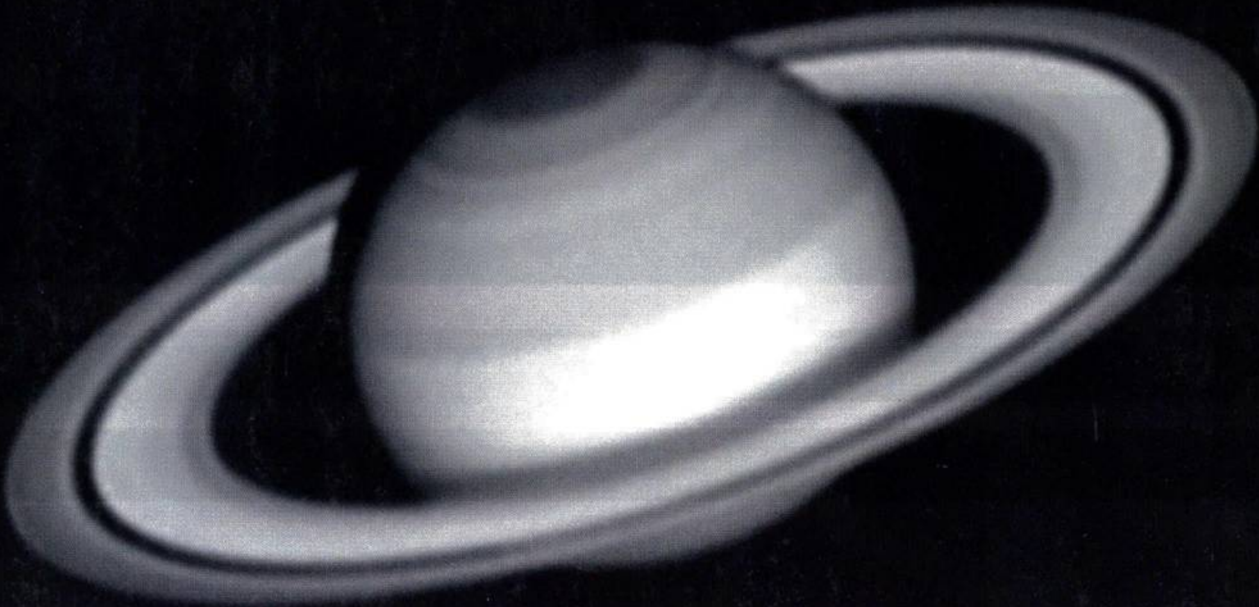

The planet Saturn, October 7, 1999. Thierry Legault of Elancourt, France, obtained this extraordinary image, a composition of fifty 0.5-second CCD exposures at f/39, with the optical system of the Meade 12" LX200 Schmidt-Cassegrain telescope. Comments Mr. Legault: "To my knowledge, this is the first amateur image of Saturn that clearly shows the Encke division — only 0.05 arc seconds wide and located very near the rings' outermost edge, about 80% of the distance from the Cassini division. Several planetary specialists who have seen this image stated that this level of resolution is rare even with professional Earth-based instruments."

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